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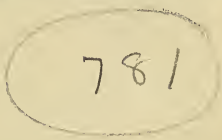

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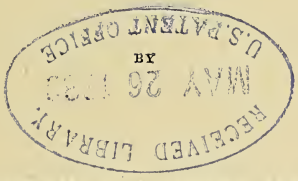
ADDENDUM TO PAPER ON AUSTRIAN FIELD GUNS.

With regard to the M.V. given at p. 2 and elsewhere of the 9^{c} Austrian gun, it seems very doubtful whether it is really so high as shown. It is hoped soon to furnish more exact information as to this point.

THE NEW AUSTRIAN FIELD GUNS.



CAPTAIN J. F. OWEN, R.A.,

(*Captain Instructor, Royal Gun Factories*).

THE new Austrian field pieces, the exact dimensions of which are given in Table I., are constructed of the so-called Uchatius "steel bronze"—an alloy of 92 parts copper and 8 parts tin—which will be found fully described, so far as known, in a paper published in "Proceedings, R.A. Institution," Vol. IX., No. 4 of 1875. The absolute details of the process of casting and subsequent treatment of piece are kept a profound secret;* although there is probably not very much to learn, save on some minor points. It seems likely that during the process of casting, the alloy is kept in a state of rotation; and we know that it is cast in chill, and subsequently compressed, as to the surface of the bore, by forcing through the latter, by means of hydraulic pressure, steel mandrels gradually increasing in size—the object aimed at being to secure uniformity of structure, freedom from tin spots, and a very hard and smooth interior surface, as well as to gain an advantage theoretically by placing all but the innermost layers in a state of initial tension increasing in amount towards the exterior.

---

* Even the instructing officers of the Artillery Cadet School in the Arsenal itself are not allowed entrance into the gun foundry.

Table I.

(Dimensions, &c., of the Guns.)

Nature of piece.	Weight.		Total length of gun.		Length of rifled bore.			Calibre. Bore.		Calibre. Powder chamber.		Twist.		Grooves. Number.	Grooves. Depth.	Grooves. Width.	Weight of common shell.	Bursting charge common shell.	M.V.	Value of log $\frac{d^2}{w}$	Velocity and energy. 2000 yds.		4000 yds.	
																					V.	E.	V.	E.
Austrian:—	cwt.	kil.	ft.	cm.	ft.	cm.	cals.	ins.	cm.	ins.	cm.	cals.	angle of		ins.	ins.	lbs.	lbs.	f.s.		f.s.	f.t.	f.s.	f.t.
9c	9·6	487	6·6	206	4·78	146	17	3·43	8·7	3·86	9·8	45	$3\frac{1}{3}°$	24	0·05	0·32‡	16·1	0·40	1542	$\bar{1}$·8638	940	99	742	63
8c	5·9	299	6·4	195	4·68	143	19	2·95	7·5	3·35	8·5	45	$3\frac{1}{3}°$	24	0·05	0·32	9·5	0·22	1397†	0·0619	781	40	580	22
German:—*																								
9	9	457	6·9	210	4·9	149	16·9	3·46	8·8	3·9	10·0	50	$3\frac{1}{2}°$	24	0·05	0·32‡	15·4	0·62	1456	$\bar{1}$·8907	903	87	710	54
8c	7·7	390	6·9	210	5·0	153	19·2	3·09	7·85	3·6	9·2	50	$3\frac{1}{2}°$	24	0·05	0·32	11·2	0·44	1525	$\bar{1}$·9308	896	62	692	37
English:—																								
16-pr.	12	609	6·2	190	4·8	145	16·7	3·6	9·1	—	—	30	6°	3	0·11	0·8	16·3	1·00	1365	$\bar{1}$·9085	871	86	684	33
9-pr.	6	305	5·9	180	5·1	155	20·8	3·0	7·6	—	—	30	6°	3	0·11	0·8	9·0	0·50	1390	Nil.	824	42	627	25

* The data as to German guns are taken from the new work by Captain Wille, of the German Artillery, entitled "Das deutsche Feld-Artillerie-Material von 1873," (Berlin, 1876), which is, I understand, now being translated by Captain Ellis, R.A.

† The M.V. of the 8c Austrian gun is taken from the "Revue d'Artillerie," October, 1876, as it is not given in the Austrian pamphlet mentioned.

‡ These grooves (termed *progressive*) get narrower towards the muzzle, and the lands therefore proportionally wider.

Until very recently it was not possible to obtain authoritatively exact data as to these new guns; though in the "Revue d'Artillerie," and in a note by Colonel Goodenough, R.A., Assistant Director of Artillery, in our Institution Papers,* some information is given concerning the same.

A pamphlet† just published in Vienna, however, dated 1877, affords most of the required data; dimensions, weights, &c., found scattered through the pamphlet, have for convenience been thrown into tables‡ in the following paper, and the matter much reduced in bulk.

The new guns are:—

(1) *Heavy Field Batteries.*—The 9^c of 9·6 cwts. Calibre 3·4 ins. (8·7^c), throwing common shell of 16 lbs., with a charge of 3·3 lbs. and muzzle velocity of 1548 f.s. Gun detachment, 8 men.

(2) *Light Field Batteries and Horse Artillery.*—The 8^c of 5·9 cwts. Calibre 2·95 ins. (7·5^c), throwing common shell of 9·5 lbs., with a charge of 2·09 lbs. and muzzle velocity of 1397 f.s.§ Gun detachmnt, 7 men.

The manufacture of these pieces is so rapidly progressing that it is hoped the equipment of the whole field artillery will be complete by April next. The armament proceeds at the rate of about 150 pieces per month, fully equipped; and in the beginning of December 1876 over 800 guns were completed, as I was informed, in Vienna. Should the hopes of the Austrian authorities be fulfilled, they will have accomplished a great feat in replacing the whole of their field guns (some 1500 in number) by a new armament manufactured in about 15 months time.||

The author of the Austrian pamphlet mentioned, after stating that, owing to the introduction of the Uchatius guns, a new epoch has arisen for the Austrian artillery, and pointing out that for this reason the matter must be one of the greatest interest to the whole army, goes on to describe gun and equipment in detail as follows:—

I.—The Gun proper.

The material of which this is composed is mentioned, and we are told that steel-bronze approaches the ideal of a magnificent gun-metal, surpassing all others known—a conclusion we may well differ from, both as to steel alone or in combination with wrought-iron. Still, for political and econo-

---

* Short Notes, No. 115, January, 1875.

† This pamphlet ("Die neuen Feldgeschützen Oesterreiche Uchatius-Kaunonen von einem K.K. Artillerie Officier," Wien, 1877) bears marks of being somewhat hastily written. It has had, however, a great sale in Austria as the first full account published, and is substantially correct, I was informed by officers in Vienna.

‡ German and English field pieces are also entered for comparison in one or two cases.

§ *Vide* note †, p. 2.

|| The total number required is 2000, but of these 1500 are sufficient for the artillery of the active army—the remaining 500 being for reserve. According to the "Revue d'Artillerie," Feb. 77, there were completed at the end of 1876, 1300 pieces, of which 600 were actually in the hands of the troops.

mical reasons, it may have been most judicious for Austria to adopt this material.

Fig. 1.

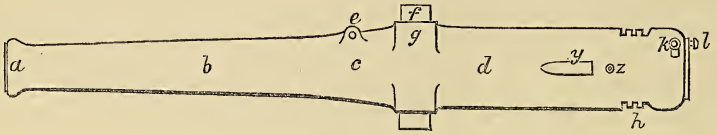


Fig. 2.

(*A.*) *The* 9^{c} *Gun** is shown in Figs. 1 and 2. The axis of the trunnions is in the same horizontal plane as that of the piece, and the trunnion arms themselves are hollowed out conically on the face. The piece is vented vertically through the metal of the piece a little in front of breech-block slot. The latter is cut laterally near the breech end right through the piece. The gun is sighted at the right side with a small screw sight, screwed into a patch on the gun in front of the trunnions, and a tangent sight, secured in an inclined socket, *k*, at breech end of the piece. The clamping screw for this socket is shown at *l* (Fig. 1).

Upon the upper surface of the gun, a little in advance of the vent, is a flat surface (*y*, Fig. 1), for the reception of a quadrant, if necessary.

At the breech end the gun terminates in a plane surface at right angles to the axis of the piece, with the corners rounded off.

Looking at Fig. 2, we see that the bore, shot, and powder-chambers have different calibres, as given in Table I., and that only the bore proper (8·7^{c} in calibre) is rifled; the rifling being square, and many-groove, with a twist of 1 in 45.

Fig. 3.

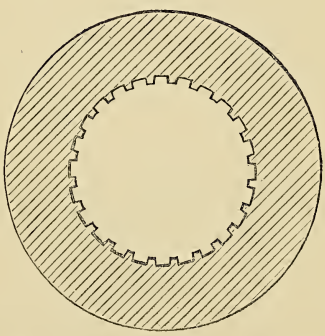


Fig. 4.

* This description will also answer for the 8^{c} (7·5^{c}) gun which only differs from the 9^{c} (8·7^{c}) in dimensions as shown in Table I.

A copper bush is screwed into the breech end of the powder-chamber, for the reception of a copper Broadwell ring (*k* Fig. 2, and section Fig. 4). This ring forms a gas-tight joint with the face of the copper plate (*a*, Fig. 6) of the breech block.

The front inner face of the breech-block slot (*l*, Fig. 2) is at right angles to the axis, but the rear face is slightly inclined. The upper and lower surfaces are symmetrical as to the axis. From the latter project the ribs* (*l l*, Fig. 2), forming a run or groove, *r*, between them. The ribs serve to guide the breech block, and the slot, *r*—as we shall see—affects the loading cylinder (*k*, Figs. 5 and 6) by means of the studs, *f f*, projecting from the latter.

Over the right-hand opening of the slot for breech block is secured by screws the so-called breech-block cover, for protection of the projecting portions of the breech block from dirt and damage. The covering is completed by means of a leather cap.

Near the left side a vertical slot is bored through the metal of the upper surface of the gun and into the slot, through which the stop pin or stud† (*vide* next page) is passed into a groove on the surface of the breech block, so as to prevent the latter being withdrawn too far.

Fig. 5.

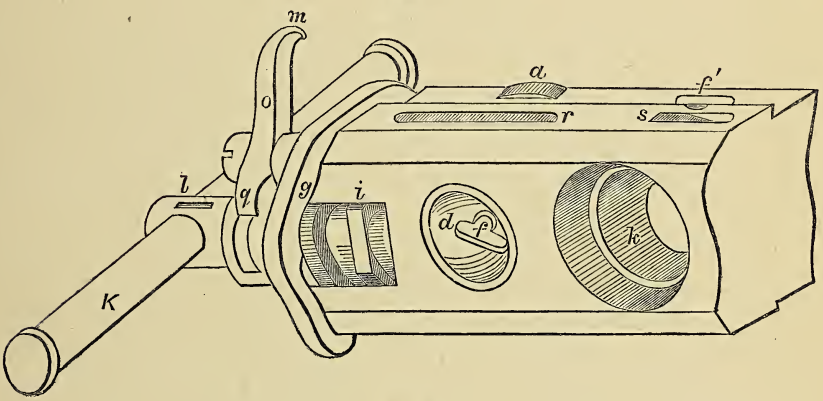
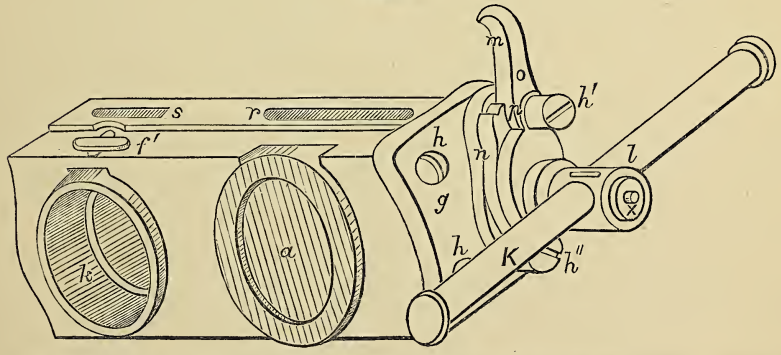


Fig. 6.



* These ribs are portions of the thread of a large-pitched screw.

† In the German field guns, the removeable steel vent answers the same purpose.

(*B.*) *The Breech Block* (Figs. 5 and 6).—This is also of bronze-steel, and rectangular. The front and back faces are plain, but the latter not parallel to the front face, but slightly inclined. Along the upper and under surfaces run a projection and deep groove (like a rabbet), ensuring, together with the ribs, *l*, a perfect fit when the block is home.

The loading cylinder (*k*, Figs. 5 and 6) is also of bronze, cylindrical, and dovetailed into the breech block as shown, so as to be capable of movement backwards and forwards. Square-headed projections from this cylinder are acted on by the studs, *f f* (which grip them), as these studs pass along the groove, *r*, when the breech block is pushed home or withdrawn.

To make a perfect gas-tight joint with the Broadwell ring in the end of the powder-chamber, the breech block is furnished with a copper plate (*a*, Fig. 6), which has on the back six holes, any one of which will fit over a stud in the hollow cast in the block to receive the plate. The position of the plate in the block can thus be altered in case of wear at any particular portion. This plate is further dovetailed into the block, and secured from any movement of translation by the screw (*f*, Fig. 5), which passes through from the rear face of the breech block, into which its head is countersunk.

To the left end of the breech block is attached the arrangement for moving it, and for securing it in position. This consists of the plate (*g*, Fig. 5), secured by the screws (*h h*, Fig. 6), through which passes the spindle of the square-threaded screw (*i*, Fig. 5), which carries the cross handle (*K*, Fig. 6) at the outer end. The thread of the screw, *i*, is so cut that when the handle *K* is horizontal, no part of the thread projects beyond the rear face of the block, and the latter can be moved laterally in the slot until this thread comes opposite the female thread cut for its reception in the rear face of the breech-block slot; a half-turn of the cross handle (bringing the same vertical) then causes the screw to bite and sends the breech block well home.

The cross handle is of iron, covered with leather. In order to prevent it (and so the screw, *i*) moving when not required to do so, it is secured in one or other of the two necessary positions by means of a catch (*m o*, Fig. 6), acted on by the bent spring (*n*, Fig. 6). The catch pivots on the screw, *h*, and has on the underside two noses, *p* and *q*, sliding in a groove running partly round the exterior of the axis of the screw (as shown in Fig. 5). The spring, *n*, is secured by one of the other screws, *h*, and is so arranged that when it presses down the nose, *q*, of the catch, the handle is retained in the vertical position, the screw being home in the gun, and the breech-block so secured in its place. A slight pressure on the long arm, *o*, of the catch overcomes the spring and releases the nose, *q*, when the handle is free to move until it becomes horizontal, when the spring presses on the second nose, *p*, and secures the handle in a new position. As the thread of screw is now withdrawn into the block, the latter can be moved outwards (towards the left), and when the loading is completed, the arm, *o*, is again pressed and the movements reversed, and so on.

In order to control the amount of movement of the breech block in the slot, two grooves (*r* and *s*, Fig. 5) are cut in its upper surface, into which the end of a stop fits, which is pressed down by a spring. As a rule, this stud or stop fits down into the groove, *r*, the length of which only allows of the breech block being withdrawn until the loading cylinder (Fig. 5) comes opposite the bore. In case, however, it be necessary to examine or

exchange the copper plate (*a*, Fig. 6), the pressure of the spring upon the stop is relieved, and the block drawn out until the stop falls into the second groove (*s*, Fig. 5), when the spring is again allowed to act, preventing the block being drawn out further than is necessary for the purpose required. If the block has to be altogether removed, it is only necessary again to relieve the pressure of the spring on the stop and to draw out and remove the block.

(*C.*) *The Vent.*—As already mentioned, this strikes the powder-chamber a little in front of slot. (*Vide* Fig. 2). Its position is perpendicular.

The vent bush is of copper, in two pieces, the lower (which embraces the upper) being pressed up from the bore. The bottom (which projects slightly into the chamber) is rounded off.

(*D.*) *Sighting.*—This is similar with both guns. The length of the line of sight is one metre.

There are two sights—a tangent sight and a screw foresight—both of bronze.

Fig. 7.

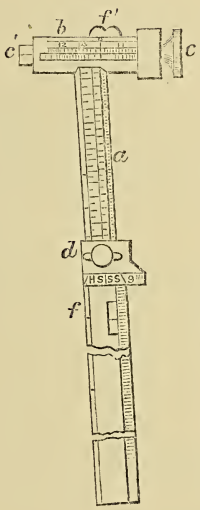


Fig. 8.

(1) The tangent sight (Fig. 7) consists of a lower portion or socket, *f*, with its head, *d*, and of the tangent scale, *a*, with its cross-head, *b*.

The socket fits into a hole bored in the gun on the right-hand top of breech end (*k*, Fig. 1), being there clamped by the screw, *l*. It is round, with the exception of a flat face cut on the right rear surface for a scale of metres, and another on the left to prevent still further any lateral movement in the gun.

The tangent scale, *a*, slides freely up and down in this socket, or lower portion, and is furnished with four scales.

On the front face are two scales, viz.—

Left. ... HS. scale, common shell { 400 to 6000 schritt. / to yds.

Right... SS. " shrapnel " { 600 to 4000 schritt. / to yds.

On the left half-rounded side, and also on the socket, *d*,

HW. scale, common shell (reduced charges) { 500 to 2500 schritt. / to yds.

and on the right half-rounded side,

Scale of metres up to 460.

Before use, the sight socket is secured and clamped in the gun.

The tangent scale is alone used, unless for very long ranges, when it would be too short. In this case it is firmly clamped in the lower portion, with the lowest graduation of its metre scale in line with the top of the latter, and the clamping screw of the socket being loosened, the whole sight is raised or lowered as required, and clamped when necessary by the clamping screw of the socket.

The cross-head of the tangent sight is parallel to the axis of the trunnions, and so at an angle with the tangent sight, which, with the socket, is placed at the necessary angle to make up for permanent deflection.

In order to make up for wind, &c., deflection of 15^{mm} right and 25^{mm} left can be given by means of the cross-head.

(2) The foresight (Fig. 8) is a small screw sight of steel bronze (blackened), which screws into the patch (*e*, Fig. 1) on the right side of the piece, a little in front of the trunnions.

II.—Ammunition.

(*A.*) *Projectiles.*

These are of four kinds—common shell, shrapnel, carcass,* and case. Rotation is given by means of four copper rings pressed into undercut rings round the projectile, and which are cut through by the lands.

The number of rounds per gun, where carried, weights, charges, &c., are given in Tables II. and III.

* It would appear from the fact of carcasses being carried, and from the small charges of the common shell and their peculiar construction, that the latter are looked upon only as mankilling projectiles, in much the same sense as our B.L. segment were.

TABLE II.—8^{c} Gun.
(*Giving details as to Ammunition.*)

Nature.	Total rounds per gun.	With gun.	With ammn. wagon.	Powder charge of gun.*		Weight, full.		Bursting charge.		Muzzle velocity.		Number of bullets.	Weight of bullets to the		Remarks.
				lbs.	kil.	lbs.	kil.	ozs.	grs.	f.s.†	m.†		lb.	kil.	
Com. shell..	102	24	78	2·09	0·95	9·5	4·31	3·5	100	1397	436	—	—	—	
Shrapnel, do.	36	12	24	〃	〃	?	?	?	?	?	?	?	?	?	
Carcass.....	6	Nil.	6	〃	〃	8	3·64	—	—	?	?	—	—	—	
Case	8	4	4	〃	〃	10·4	4·73	—	—	?	?	72	?	?	
Total ...	152	40	112	—	—	—	—	—	—	—	—	—	—	—	

* There are also a certain number of reduced charges carried. (*Vide* p. 14.)
† Taken from "Revue d'Artillerie," October, 1876.

TABLE III.—9^{c} Gun.
(*Giving details as to Ammunition.*)

Nature.	Total rounds per gun.	With gun.	With ammn. wagon.	Powder charge of gun.*		Weight, full.		Bursting charge.		Muzzle velocity.		Number of bullets.	Weight of bullets to the		Remarks.
				lbs.	kil.	lbs.	kil.	oz	gr.	f.s.	m.		lb.	kil.	
Com. shell...	85	20	65	3 3	1·5	16·14	7·337	6	170	1542	470	—	—	—	
Shrapnel do.	30	10	20	〃	〃	15·55	7·07†	3	83	?	?	163†	—	—	
Carcass.....	5	Nil.	5	〃	〃	13·35	6·07	—	—	?	?	—	—	—	
Case	8	4	4	〃	〃	16·47	7·49	—	—	?	?	120	—	—	
Total ...	128	34	94	—	—	—	—	—	—	—	—	—	—	—	

* There are also a certain number of reduced charges carried. (*Vide* p. 14.)
† Not given in book translated. The weight is taken from "Fremde Artillerie," by R. Stein. Berlin, 1875.

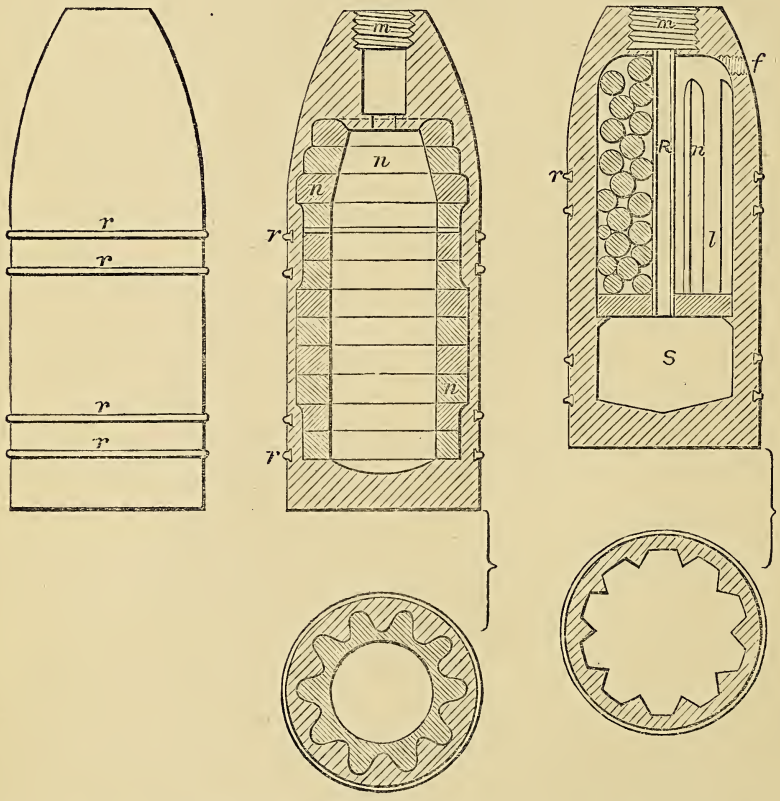
(1) *The common shell* (Figs. 9 and 10) is of the so-called double-wall description, which has for its object to give as many splinters as possible, of a size sufficient to kill a man.

The inner wall is cast so as to consist of twelve horizontal and parallel rings, these rings, being grooved also lengthwise by deep lines of weakness; so that this inner wall consists of a number of pyramidal pieces with the

bases in close contact, forming the smooth interior of the shell. Over this inner wall is cast the exterior portion, which forms the outer wall, the bottom, and the head of the projectile. Two pairs of undercut grooves run round the exterior of the shell, into which are pressed the four copper rings which give rotation.

The fuze-hole is separated from the interior by a diaphragm cast in the neck of fuze-hole, having a large fire-hole. Above this is a cylindrical portion, enlarged and threaded towards the top, for the reception of the percussion fuze (Fig. 13), described at p. 12.

Fig. 9. Fig. 10. Fig. 11.

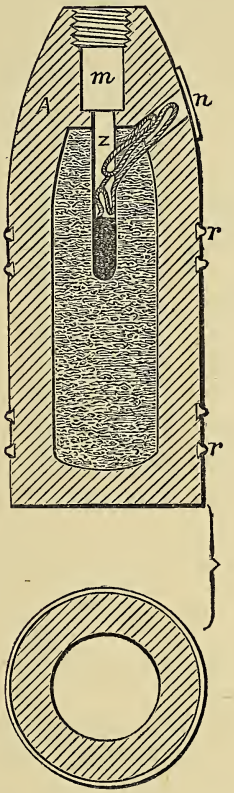


(2) *The shrapnel* (Fig. 11) resembles our own in having the powder charge at the bottom, separated from the bullets by a thick diaphragm, and ignited through a tube passing down the centre of the shell from the fuze-hole.

It is cast in one piece, is rather shorter than the common shell, and has ten deep longitudinal lines of weakness in the bullet chamber, in order to allow of its opening readily and to give more splinters on bursting. This shell is furnished with the time fuze (Fig. 15) described at p. 13, which screws into the fuze-hole.

The shrapnel, we are told, are intended for fire against troops under cover or in column formation.

Fig. 12.



(3) *The carcass* (*vide* Fig. 12, above) outwardly resembles common shell in shape and size, but it is cast with very thick single walls, and in the ogival head has three fire-holes covered with pitch-plaster. The interior is filled with a carcass composition, and a channel down the centre, as well as other channels leading to the fuze-holes, are filled with mealed powder, with quickmatch leaders.

The fuze-hole is adapted for the same percussion fuze as used with common shell.

(4) *The case* consists of a zinc cylinder filled with bullets, composed of lead and antimony, between which molten sulphur is run. The ends are closed by zinc plates, secured by turning down the ends of the case, as we do, and the base is strengthened by a second and thicker plate, also of zinc. To prevent the case being rammed too far in loading, there is a projecting ring round the exterior, at the same distance from the base as the foremost copper ring on the shell. The base is supplied with a handle made of galvanized iron wire.

(*B.*) *Fuzes.*

1. *The Percussion Fuze* (Fig. 13) is used with the common shell and carcass. It consists of (1) a brass fuze-hole screw, *a*; (2) the fuze-screw, *b*; (3) the percussion pellet and capsule, *p*; (4) the securing screw-plug, *c*; (5) the outer fuze-case, *d*; (6) the upper striker, *f*; (7) the lower striker, *s*; (8) the copper safety cap, *h*; (9) the percussion pin, *n*.

Fig. 13.

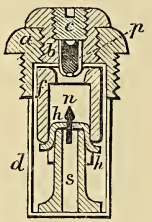


Fig. 14.

(1) The fuze-hole screw is of brass. Its thread fits into that of fuze-hole, and it serves to carry and support the other portions of the fuze.

(2) The fuze screw holds the capsule, *p*, and is threaded for the screw, *c*.

(3) A copper capsule, filled with a pellet of fulminate of mercury and having a small hole covered with a disc, fits into the fuze screw.

(4) The securing screw-plug, *c*, keeps the capsule with detonating composition firmly in place.

(5) The brass case, *d*, contains the percussion arrangements, and has in the base a circular fire-hole.

(6) The upper striker, *f*, is a brass cylinder open at both ends, the upper surface of which rests against the shoulder of the fire-hole screw, and the lower surface on the safety-cap.

(7) The lower striker, *s*, is also of brass, and has a spreading base and a cylindrical stem, *s*, the exterior diameter of which is considerably smaller than the smallest interior diameter of the upper striker. To the upper end is secured the pin, *n*, the point of which projects through the safety-cap above.

(8) Between the two strikers is the copper safety-cap, *h*, shown also in plan and section in Fig. 14. It prevents the stem of the lower striker entering the upper striker and exploding the fuze by means of the pin, *n*. The rim of this safety-cap is split at intervals, so as to allow of eight portions being bent at right angles. These bent portions are strong enough, under ordinary circumstances, to keep the strikers in their normal position.

The action is simple enough. On the shock of discharge, the upper striker, through its *vis inertia*, bends down the rim of the safety-cap and falls down over the cylinder of the lower striker to the bottom of the fuze, leaving the striking pin uncovered.

On impact, the two strikers are thrown forward together, the needle

explodes the pellet, *p*, and the flame, passing backwards through the fuze, ignites the charge.

2. *The Time Fuze* (Fig. 15).—This somewhat resembles our own B.L. time fuze, except in the percussion arrangement. It consists of—

Fig. 15.

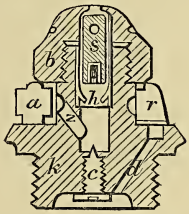


Fig. 16.

(1) The body, *k*, threaded on its lower circumference to fit into fuze-hole, having a projecting shoulder on which is placed a ring of fuze composition, and above that a neck threaded to receive the cap, *b*. The upper portion of the body is hollow, and through the centre of the base is passed a screw, *c*, with a needle-point projecting into the body of the fuze.

(2) The brass cylindrical striker, *s*, furnished with a pellet of detonating composition in the lower end, fitting partly into the neck of fuze and partly into the cap.

(3) The safety pin (not shown), which would pass through the cap and the hole shown in the striker.

(4) The copper safety capsule, *h*, shown separately in Fig. 16. Portions *l l* of the lower rim of the capsule are bent inwards, so as to support the striker.

(5) The band of fuze composition, *a r*, resting on the shoulder of the body.

The safety-pin is withdrawn just before the shell is placed in the gun, and the fuze acts subsequently thus:—Upon the shock of discharge, the *vis inertia* of the striker overcomes the resistance of the bent rim of safety-capsule, and falling to the bottom of the hollow in body of fuze, the detonating pellet is exploded by the pin, *c*, the flame passes through the channel, *z*, in the body, and ignites the ring of fuze composition, which burns away until the point for which it is set is arrived at, when the flame fires mealed powder in a lower channel, *o*, the fire from which, passing through the fire-channel, *d*, in the body of the fuze, ignites the shell charge.

(*C.*) *Cartridges.*

These are made of silk cloth,* and contain a large-grain powder 0·24 in. to 0·4 in. (6^{mm} to 10^{mm}) in diameter of grain.

They are of two descriptions—(1) service, and (2) reduced.

---

* Sewn partly by hand and partly by sewing machine.

(1) The service cartridges are carried in the proportion of one per round of projectile, and contain 3·3 lbs. (1·5^{k}) of powder for 9^{c}, and 2·09 lbs. (0·95^{k}) for the 8^{c} gun.

(2) The reduced charges (meant for high-angle firing), are carried in the proportion of one-fourth of the service rounds, and contain only 0·926 lbs. (0·42^{k}) and 0·5 lbs. (0·24^{k}) of powder respectively. In order to bring them up to the service size, a plug of pulped paper is made up in the cartridge.

(*D.*) *Friction Tubes.*

These are of the ordinary description.

A proportion of about 25 per cent. spare is carried in addition to the number corresponding to that of rounds of ammunition.

III.—Gun-Carriages.

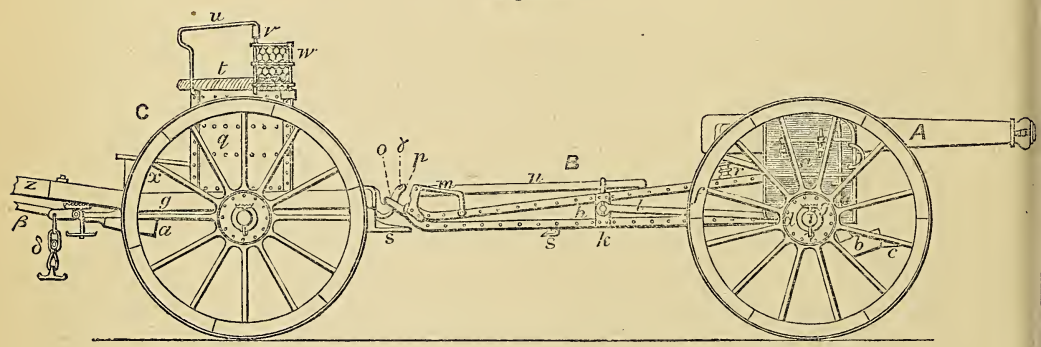
These are similar for both guns (differing only in weights and dimensions), and are constructed of steel and wrought-iron.

9^{c} *Gun-Carriage* (*Fig.* 17).

This consists of—

(1) The body, which consists of the cheeks (*h*, Fig. 17)—made of thin plates of Bessemer steel* strengthened with angle-iron—and of the bolts and plates securing them together, the trunnion plates, &c.
(2) The axletree-boxes (iron plate).
(3) Axletree of cast-steel, with its stays, and the axletree seats.
(4) Elevating arrangement.
(5) Wheels and pipe-boxes for axletree arms.

Fig. 17.



(1) *The body.*—Towards the front the cheeks are parallel, but in rear of the elevating arrangement they begin rapidly to converge, and at the trail

* Supplied by Austrian firms.

end they are both covered and secured together by the wrought-iron shoe carrying the trail-plate eye. They are further connected by two vertical iron plates with angle-iron—one near the front, and another between the elevating arrangement and point of trail—by the bolt for the axletree stays, by that of the elevating arrangement, and by the axletree boxes.

On the upper surface of each cheek is secured an iron trunnion plate, furnished with a capsquare. The front iron bolts securing these plates to the cheeks are lengthened above and made cylindrical, so as to serve as a handle or holdfast for the gunner on the axletree seat.

Just above the trail shoe is secured an iron socket for traversing handspike, capable of moving in the vertical plane, and on each side of this are the trail handles for limbering and unlimbering. The traversing handspike (of wood, shod with iron) can be pushed home in the socket for use, or when not required can be partially but not wholly withdrawn. When so partially withdrawn it can be turned up with the socket, so as to lie between the cheeks (as shown in Fig. 17), being there secured by a strap when the gun is limbered-up.

(2) *The axletree boxes* are made of iron plate, and are riveted together and to the cheeks, the lids hinging towards the rear.

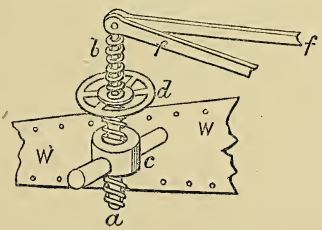
(3) *The axletree** is cylindrical, of cast-steel, and weighs 1½ cwts. (70ᵏ).† It has in certain places projecting rings round the circumference, and at each end a conical axletree arm.

The stays (*l l*, Fig. 17) serve to support the axletree itself, and to secure the whole system more firmly together. Their front ends pass round the axletree, and the rear ends are secured (*k*, Fig. 17) to the iron plates, which are fastened to the cheeks by screw bolts and nuts.

Upon the axletree, on either side, and outside the cheeks, is secured an axletree seat (*a*, Fig. 17) for one man. The seat is made of an iron frame covered with leather, furnished with a back, and provided with a leather cushion.

There is a step, *b c*, for mounting and dismounting. The leather handle shown in Fig. 17 on the outer side, assists in the same, and also serves to hold on by when the man is seated and the gun in motion.

Fig. 18.



* Each separate axletree is subjected to a severe test—a weight of 88 lbs. (40ᵏ) being dropped upon its centre from a height of 6 ft. (2ᵐ).

† With 8ᶜ, axletree weighs 1 cwt. 0 qrs. 5 lbs. (53ᵏ).

(4) *The Elevating Arrangement** (Fig. 18) has a species of differential screw. It consists of the outer left-handed wrought-iron screw (*a*, Fig. 18), the interior right-handed screw, *b*, of steel, the hand wheel, *d*, the elevating screw socket, *c*, and the elevating fork, *f*.

The interior screw, *b*, has a flat head, and is secured to the elevating fork (as shown) by a bolt. The outer ends of this fork are secured on the interior of the cheeks to a bolt passing between the latter. The thread of exterior screw, *a*, fits into that of the socket, *c*, which is free to move in a vertical plane, being pivoted between the cheeks. The upper end of *a* is furnished with the handwheel, *d*.

The arrangement allows of very rapid elevation or depression. For, supposing the handle, *d*, to be turned to the right, the exterior screw tends to elevate; at the same time, as the fork, *f*, prevents any movement of translation of the screw, *b*, this latter must also rotate as the exterior (with the nut, *c*) swings, and thus it also gives elevation. The opposite action, of course, occurs when the handle is turned to the left.

To prevent the screw running down when the gun is moved, the handle is then firmly secured by means of a strap, the end of which is fastened to one of the axletree boxes.

This apparatus can give an elevation of 24° and a depression of 9° (10^{g}).

(5) *The wheels*† resemble closely our own Madras wheels,‡ consisting of bronze nave in two pieces, 12 spokes of oak, 6 ashen felloes, an iron ring tire, and a bronze removable bearing for axletree arm.

The bronze nave is in two parts, each consisting of a cylindrical portion joined to a plate—the latter being pierced near the circumference with a number of holes corresponding to that of the spokes. In the cylindrical portion is placed a hoop or cylinder of chilled bronze, as a bearing for axletree arm. This can readily be changed when necessary.

The spokes are so formed that when their lower ends are assembled round the bronze pipe-box and between the plates, they form with the latter a complete solid nave. They are then secured by passing through the holes in the plates and through the centre of the lower end of each spoke an iron bolt, which is nutted on the exterior of the outer plate.§

The outer-end ends of the spokes are fastened, as with us, into the felloes, and the ring tire is secured over the latter by means of six screw-bolts and nuts.

The linchpins (*g*, Fig. 17), which secure the wheels on the axletree arms, have broad flat cross-heads, making their withdrawal very easy.

	ft.	c.
Width of track	5·02	(153)
Diameter of wheels ...	4·49	(137)
Dish of wheels	0·123	(3·75)

when the axis of the gun is horizontal and the piece fully equipped.

---

* This exactly resembles that used with the German field gun.

‡ Weight of wheel, 9^{c}–166 lbs. (76^{k}), 8^{c}–148 lbs. (68^{k}). The wheels of the guns are, however, interchangeable if required. The scantling of those for the 8^{c} is smaller, and the wheels therefore not so strong.

† Though it will be seen that they differ as to securing of lower ends of spokes in the nave.

§ In this it will be seen they differ much from our own.

Pressure on point of trail of unlimbered gun:—

	cwts.	k.
9c	2	(100)
8c	1½	(83)

Angle made by trail with horizontal plane, 28°.

Height of axis of trunnions above ground level:—

	ft.	in.	c.
9c	3	7	(115)
8c	3	5	(108·5)

IV.—The Limber.

The limbers for light and heavy guns are precisely similar and interchangeable, except that that of the 9c is fitted to carry 3 men, for the 8c light field batteries it is fitted to carry 2 men, and for the horse artillery to carry none at all.

The limber (Fig. 17) consists of:—

(1) The body, *g*, with axletree and limber-hook.
(2) The pole, splinter bar, swingletrees, &c.
(3) The limber boxes and seats.
(4) The wheels.

(1) *The body, g,* is made of wrought-iron, and consists of the futchells, centre piece, side and cross pieces; constituting a frame-bedding for the limber and footboard boxes, as well as carrying the axletree, pole, and limber-hook.

The futchells are joined together in front, forming a four-sided box, *z*, into which the end of the wooden draught-pole fits. Towards the rear the futchells are fastened together by a cross piece, and upon the end of the left-hand one are screwed two hooks, upon which to hang the drag-shoe and chain.

To the rear end of the centre piece is secured the limber-hook. This latter is of iron, and has a key or pin of steel, to keep the trail-plate eye on the hook. This key is fastened to the rear cross piece by a small chain.

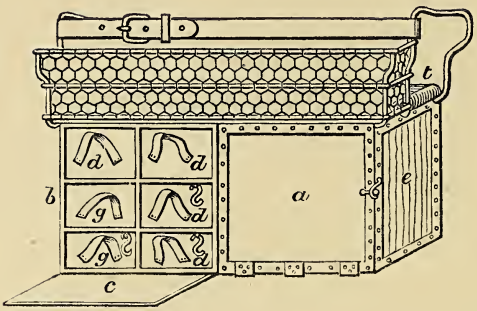
To the cross piece is also secured the plate or shoe, *s*, to serve as a support for the end of the trail during the process of limbering-up.

(2) *The pole** is of the usual description, and has on the under side an iron loop for the strap used to secure the sponge stave, which lies along under the pole, the head being placed in an open cylindrical cap, secured underneath at rear end of pole.

Underneath, across the front ends of the futchells, is secured the splinter bar, which is of iron, hollow, and is besides further secured by an iron stay on each side to the axletree arms. At each end of the splinter bar are swingletree hoops, and above an iron roughened step, for mounting and dismounting.

* The necessary wooden swingletrees for draught are of course provided, as well as the pole.

Fig. 19.



(3) *The limber box* is of iron plate, and is divided into two parts by a partition across the centre. Each part has a door opening to the rear and downwards, secured by a bolt and two hooks.

In each part are six recesses, each of which contains a wooden drawer, in which are packed cartridges, projectiles, friction tubes, &c.

The top of the box is provided with a thick leather cushion, and at the back and sides with an iron railing, across which is fastened a broad strap (*v*, Fig. 17), against which men sitting on the box may lean. Behind this is a sort of rectangular basket of brass-wire netting (*w*, Fig. 17), meant to hold cooking utensils, and so on.

The footboard box is made of wood, and secured to the futchells. It holds various small articles, and also answers the purpose of a footboard for men mounted on the limber box. Upon it and against the front of the limber box are fastened the entrenching tools.

(4) *The wheels* are precisely similar to the gun wheels (p. 16), but about 17 lbs. (8^k) lighter.

The weight of the empty limber is about 9 cwt. (460^k).

Gun and Limber.

Both 9^c and 8^c are drawn by six horses.

With the 8^c, four of the detachment ride with the piece, in the horse artillery; or are mounted (2 men on limber, and 2 men on axletree seats) for light field batteries.

With the 9^c, five of the detachment are mounted (3 men on limber, and 2 men on axletree seats).

The weights, &c., are given in the following table :—

Table IV.

(Giving Details as to Guns Limbered-up.)

Nature of piece.	Gun and limber complete.		Weight per horse.		With detachment mounted. *		Weight per horse.		Length occupied, limbered up.		Turning angle.	Smallest width of space required for reversing.		Remarks.
Austrian:—	cwt.	kil.	cwt.	kil.	cwt.	kil.	cwt.	kil.	ft.	m.	degs.	ft.	m.	
9c† Hy. Fd. Bt.	37	1870	6	312	44	2235	7·33	372	29	8·8				
8c†Lt. Fd. Bt. ...	30	1521	5	253	36	1813	6	302	28	8·52	81	21·3	6·5	
8c† H.A.	30	1521	5	253	—	—	5	253	28	8·52				
German:—														
9c† Hy. Fd. Bt.	38¼	1940	6·4	323	46½	2366	7·75	394	27·5	8·40	80	?	?	
8c† Lt. Fd. Bt. and H.A. ...	35½	1810	5·9	300	—	—	5·9	300	27·4	8·38	80	?	?	
English:—														
16-pr.†Hy.Fd.Bt.	42	2164	7	360	49	2520	8·25	420	22·9	6·98	51	32·3	9·84	
9-pr.†Lt. Fd. Bt.	33½	1833	5·7	305	37⅝	2190	6·3	365	22·4	6·82	52	32·3	9·84	
9-pr.† H.A.	33½	1833	5·7	305	—	—	5·7	305	22·4	6·82				

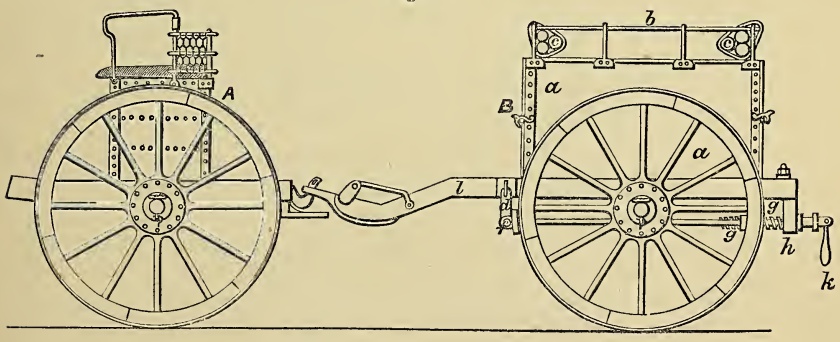
* Supposing a man to weigh about 13½ stone (85k)—14 stone in case of English gunners.
† Six horses.

V.—The Ammunition Wagon and Limber.

This is precisely similar in every way in the case of the two pieces, except that the scantling of that for the 8c being rather smaller, its wagon is slightly lighter than that of the 9c.

The wagon (Fig. 20) consists of (*A*) the limber, and (*B*) the wagon proper.

Fig. 20.



(*a*) The limber (*A*, Fig. 20) is precisely similar to, and interchangeable with, the gun limber already described.

(*b*) The wagon (*B*, Fig. 20) consists of (1) the wagon body; (2) the perch, *l*; (3) the axletree; (4) the wheels and spare wheel; (5) the break, *d*, *f*, *s*, *h*, *k*; (6) the ammunition boxes, *a*.

(1) *The body* is of iron; being a framework made of U and H iron, consisting of a centre and side pieces, united at the rear end by a cross piece. The front of the frame is formed by the two side pieces being bent at right angles, so as to meet the front end of the centre piece.

(2) There, in order to form *the perch*, they are again bent at right angles, and run close to and parallel to each other towards the front, where (*l*, Fig. 20) they are again bent—this time downwards—so as somewhat to resemble the trail of a gun, and, as in that case, the ends are covered with a shoe carrying an eye for limbering-up, as well as with a handle on each side.

(3) About the centre of the body *the axletree* is secured. This is very similar to the axletree of the gun or limber, but not interchangeable.

(4) *The wheels* are the same as those of the limber.

A spare gun wheel is carried underneath the body, as follows:—An iron block, resembling an axletree arm, and furnished with linchpin and washer, is secured to the centre cross piece of frame. Over this the pipe-box of the nave of the wheel is fitted, and the linchpin put in; the wheel is then tightly secured in its place by rope lashings, which pass through loops secured for the purpose to the under side of the frame.

(5) *The break* consists of (1) the iron breakshoe, *f*, furnished with wood blocks, which is supported by (2) the hanging pieces, *d*, so as to be capable of movement in the vertical plane. (3) the break bar, *m*, is attached to *f*, and has on its rear end a threaded socket (which in Fig. 20 is nearly obscured by the rear view of wheel). Into this socket screws (4) the male screw, *g*, of spindle, *g*, which also passes through the fixed nut, *h*. Two projections on the spindle prevent any rectilinear motion of the same, though not interfering with freedom of rotation in the fixed nut. Upon the rear end of this spindle is the break handle, *k*.

Suppose we turn this handle to the right; then the screw, *g*, rotates in the threaded socket of break bar, *m*, and, as the latter cannot turn round, the bar, *m*, is forced to move towards the rear, pressing the break-shoe with its wood blocks tightly against the circumference of the wheel.

By turning the handle to the left, the break is loosened.

(6) *The ammunition box* is placed on the body, above the axletree, with its centre rather towards the front of the latter. It consists of a large box of iron plate over an iron framework, and is divided lengthwise (across the wagon) into two portions by an iron diaphragm. Each of these portions resembles exactly one of the limber boxes already described (p. 18), except that each half has only five instead of six recesses and drawers, as the two lowest are thrown for convenience into one larger drawer. The top is also of iron plate, somewhat domed, and surrounded by an iron rail, *b*, and in two corners are secured by straps six horse-pickets (*c c*, Fig. 20).

The remainder of the space on the top would be devoted to forage, a

waterproof cover being carried with each wagon to protect the same from weather.

Above the downward bend just in front of the ammunition box is an iron footboard.

Some of the most important small stores are secured underneath the wagon, viz. :—

Handspike.	Pickaxe.
Screwjack.	Maul.

The drag shoe and chain are, as already mentioned, hung upon hooks at the end of the side pieces, while further forward is another hook for hanging the chain from when the shoe is in use.

Ammunition Wagon Limbered-up.

In width of track, size, height of wheel, &c., the wagon limbered-up resembles the gun, requiring exactly the same space for reversing, &c.* The limber box will carry three men of the gun detachment.

The weight is rather more than of gun limbered-up, as will be seen from the following table as compared with Table IV. :—

TABLE V.

Nature of gun.	Total weight.		Per horse.		With 3 men mounted.		Per horse.	
	cwts.	kil.	cwts.	kil.	cwts.	kil.	cwts.	kil.
9c	41	2086	7	348	45	2305	7·5	384
8c	37·5	1898	6·25	316	41·5	2117	6·75	353

VI.—SIDE-ARMS AND SMALL STORES.

These, we are told, are similar in most respects to those of the old equipment. They are :—

(1) Sights (already described).
(2) Quadrant.
(3) Sponge.
(4) Rammer.
(5) Extractor.
(6) Pricker.
(7) Friction tube pocket, with strap and buckle.
(8) Lanyard.
(9) Wrench for gas-check ring.
(10) Cartridge cylinder.
(11) Rammer.
(12) Handspike.
(13) Vent punch and hammer.
(14) Muzzle fid, and Cap for vent slot opening.

Besides which there are dragshoe and iron chain, a small wheel jack, entrenching tools, maul and pickets, hatchet, spades and pickaxes, cooking utensils, water

* *Vide* Table IV.

buckets, forage cords, padlocks, water-proof covers (for top of ammunition boxes), and the necessary tools. Range tables and range books are also provided.

Most of the above require no description.

(1) The details as to the sights have already been given.

(3) Piasaba grass is used (as with us) for sponge head.

(5) The extractor or unloader is a short wooden cylinder, with a hole in the head to receive the fuze, passed down from the muzzle before the rammer is employed to unload.

(9) This wrench is meant to remove the Broadwell copper ring, when it requires to be replaced. It has a short and long arm, and a hinged tooth or catch. The latter catches the ring inside, while the short arm, bearing against the vent slot, gives a fulcrum for the long arm.

VII.—Packing.

The number of rounds of ammunition carried with gun and ammunition wagon are given in Tables II. and III.

The mode in which they are packed is as follows:—

The wooden drawers, already mentioned, which fit into the pigeon-holes or divisions of the boxes, are marked—

H.	Common shell	(*Hohlgeschoss*).
S.	Shrapnel	"
B.	Carcass	(*Brandgeschoss*).
K.	Case	(*Kartätschen*).

while drawers with cartridges have no distinguishing letter.

The large drawers of ammunition wagon (p. 20), are used to hold gun small stores, &c.

9c *Gun.*

Gun limber box.

- 4 drawers, H, with 20 common shell.
- 2 " S, " 10 shrapnel "
- 2 " K, " 4 case.
- 2 " K, " 12 service cartridges.
- 2 " " 20 " "
- 2 " " friction tubes and small stores.

Ammunition wagon limber. } Exactly same as gun limber.

Ammunition wagon. (Front portion.)

- 5 drawers, H, with 25 common shell.
- 1 drawer, B, " 5 carcasses.
- 2 drawers, " 20 service cartridges.
- 1 drawer, " 4 reduced "
- " 12 service "
- 1 " " 20 " "
- 1 " " reserve stores.

Ammunition wagon. (Rear portion.)

- 4 drawers, H, with 20 common shell.
- 2 " S, " 10 shrapnel "
- 4 " " 40 service cartridges.
- 1 drawer, " reserve stores.

8c *Gun.*

Gun or ammunition wagon limber.

- 4 drawers, H, with 24 common shell.
- 2 " S, " 12 shrapnel "
- 2 " K, " 4 case.
- " 16 service cartridges.
- 2 " " 24 " "
- 1 drawer, " small stores.

Ammunition wagon. (Front portion.)

- 5 drawers, H, with 30 common shell.
- 2 " S, " 12 shrapnel "
- 2 " K, " 4 case.
- " 16 service cartridges.
- 2 " " 24 " "
- 1 drawer, " small stores.

Ammunition wagon. (Rear portion.)

- 4 drawers, H, with 24 common shell.
- 2 " S, " 12 shrapnel "
- 4 " " 48 service cartridges.
- 1 drawer, " small stores.

VII.—Preservation and Shooting.

The author, under this head, merely mentions that the copper plate upon the breech block requires most particular attention, describes the process of loading (which is the same as that of any similar B.L. gun), and then goes on to give the mean results of a great number of common shell, shrapnel, and case, fired at targets representing cavalry in column. These results are embodied in the following table:—

Table VI.

(Showing Mean Results of Firing with different Projectiles at Targets representing Cavalry in Column.)

Nature of gun and projectile.	Target.	Distances.*																								Remarks.
		yds. 144	schritt 200	yds. 216	schritt 300	yds. 288	schritt 400	yds. 360	schritt 500	yds. 432	schritt 600	yds. 720	schritt 1000	yds. 958	schritt 1330	yds. 1080	schritt 1500	yds. 1440	schritt 2000	yds. 1800	schritt 2500	yds. 2160	schritt 3000	yds. 3600	schritt 5000	
9c gun:—																										
Hits with: Case	(*a*) 3 targets in column, with intervals of 65 ft. (20m), each target 8·9 ft. (2·7m) high, and 118 ft. (36m) long.	—	—	—	—	86	86	—	—	68	68	—	—	—	—	—	—	—	—	—	—	—	—	—	—	The number of hits per round are shown in horizontal columns.
Hits with: Shrapnel		—	—	—	—	—	—	—	—	—	—	124	124	—	—	144	144	187	187	142	142	121	121	—	—	
Hits with: Com. shell		—	—	—	—	—	—	—	—	—	—	—	—	148	148	—	—	114	114	—	—	93	93	—	—	
Hits with: " "	(*b*) 7 similar targets at same distances behind each other.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	36	36	
8c gun:—																										
Hits with: Case	Target (*a*)	65	65	59	59	—	—	46	46	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Hits with: Shrapnel		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Hits with: Com. shell		—	—	—	—	—	—	—	—	—	—	—	—	113	113	—	—	70	70	63	63	51	51	—	—	

* Taking a schritt = 0·66m = 0·72 yds.

REMARKS ON FOREGOING.

Taken altogether, it is evident that the present Austrian armament is an immense advance upon that which she has up to this time possessed, and that for the present the power of her field guns is quite equal, if not superior, to that of the German Krupp guns of latest pattern, while their cost is about two-thirds of the Krupp steel field pieces.*

(1) The heavy piece, of about the same calibre as the German, but half a cwt. heavier, throws a common shell of 16·1 lbs. against 15·4 lbs., and with a higher velocity; so that at 2000 yds. it has 40 f.s. more velocity than the German shell.

(2) The light piece, on the other hand, with a calibre 0·14 in. smaller than the German light gun, is 1½ cwt. lighter, and throws a common shell of 9·5 lbs. against 11·2 lbs. The muzzle velocity, also, is much lower than that given by the German piece.

Whether the metal used will not deteriorate under firing, is, however, according to our ideas, still a question. I find the following statement in the foreign correspondence of an English daily paper:—"The Emperor, Francis Joseph, in a new year's letter (1877) to the General Inspector of Artillery, has expressed his satisfaction at the surprisingly rapid production of the 1100 Uchatius guns; but now it appears (16. 1. 1877) that the projectiles†—to which the guns owe their chief excellence (?)—can only be prevented by great caution from bursting in the gun. The double iron casing is too thin, the indentations which cause the bursting of the case (?) into a number of small pieces too deep, and on the battlefield the same precautions are not possible as on the practising ground."

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* Taking into consideration the fact that Government possessed a large stock of old bronze guns, the metal of which could be utilised.

† The double shell described at p. 10 of this paper.

PRINCIPLES OF GUNNERY.

RIFLED ORDNANCE.

BY

CAPTAIN J. SLADEN, R.A.

(*Professor of Artillery, R.M. Academy, Woolwich*).

CHAPTER I.

Terms used in Gunnery.

Object of Rifling Guns.—Projectile centred.—Line of Fire.—Trajectory.—The Plane of Fire.—Line of Sight.—Angle of Elevation.—Angle of Departure.—Jump.—Angle of Fire.—Angle of Descent.—Range.—Terms distinguishing the various Natures of Artillery Fire.—Direct Fire.—Indirect or Curved Fire.—High-Angle Fire.—Front Fire.—Oblique Fire.—Enfilade Fire.—Reverse Fire.—Deflection.—Muzzle Velocity.—Resistance of the Air.—Remaining Velocity.—Retardation.—Striking Velocity.—Horizontal Velocity.—Vertical Velocity.—Gravity.—Terminal Velocity—Calibre.—Windage.—Clearance.—Disadvantages of Windage.

Object of rifling guns.

With smooth-bore guns, a frequent cause of inaccuracy at moderate ranges is due to the uncertain rotation communicated to the projectile in the bore of the gun; so that it never can be confidently predicted whether the projectile will deflect to the right or left. With rifled guns, on the contrary, rotation is impressed on the projectile by means of spiral grooves cut in the gun; so that the rotation is no longer uncertain, but always takes place in a fixed direction, giving a constant deflection, which can be allowed for in laying the gun.

Moreover, it becomes possible, by giving sufficient rotation to an elongated projectile, to keep it point first during its flight through the air; and so to diminish the effects of the resistance of the air,* by increasing the ratio of the weight of the projectile to the diameter of the bore, and also by giving the head of the projectile any desired shape. Hence arises greater accuracy, greater effect of shell, greater penetration, and a flatter trajectory.

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* See pamphlet by the author, "The Merits of a Large Bore and Small Bore Contrasted." ("Proceedings, R.A. Institution," Vol. VII. p. 273.)

The intensity of effect is much greater, then, with rifled than with smooth-bore ordnance, and any required result can be attained with a much less expenditure of time and *matériel.*

Accuracy of fire, combined with *effect* of shell, are the great objects to be attained by rifled ordnance.

Accuracy of fire increases (*cæteris paribus*) with the velocity. The effect of shell increases with its weight, and its capacity for holding a larger bursting charge or a greater number of bullets.

Projectile centred.

In order to secure the greatest accuracy of fire, it is necessary that the axis of the projectile should coincide at the muzzle with the axis of the gun from which it is fired. The projectile is then said to be *centred.*

Line of fire.

Trajectory.

The *line of fire* is the *direction* of motion of the projectile at the muzzle of the gun. This primary direction of motion is changed, during the flight of the projectile in the air, by various forces—viz., the force of gravity, wind, resistance of the air, &c.—which shape the path of the projectile in the air. This path is a curved line, and is called the *trajectory.*

The line of fire is, then, a tangent to the trajectory at the muzzle.

The plane of fire.

The *plane of fire* is the vertical plane passing through the line of fire.

Line of sight.

The *line of sight* is the straight line passing through the notch of the tangent sight, the top of the fore sight, and the object aimed at.

Angle of elevation.

The *angle of elevation* of a gun is the angle which the axis of the gun makes with the line of sight,* and is measured by the number of degrees and minutes at which the tangent scale is set.

Angle of departure.

The *angle of departure* is the angle which the line of fire makes with the line of sight.

Jump.

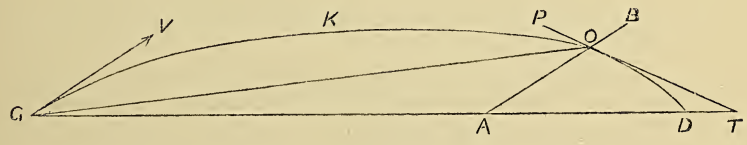
The difference between the angle of departure and the angle of elevation is sometimes called the *jump.* It varies with different guns, and with different charges, &c., in the same gun.†

Angle of fire.

The *angle of fire* is the angle which the line of fire makes with the horizontal plane.

Angle of descent.

The *angle of descent* is the angle which a tangent to the trajectory at the point of impact makes with the horizontal plane.



Suppose *G* to represent the muzzle of the gun, *O* the object aimed at

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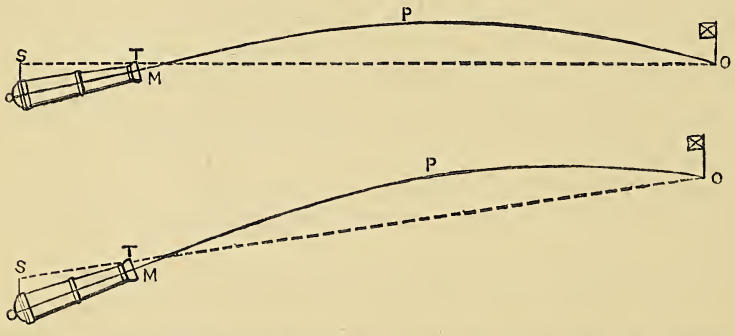
* More accurately with the *projection* of the line of sight on a vertical plane through the axis of the gun, on account of the inclination of the tangent scale to the left, to allow for *derivation.* (See p. 29.)

† See "Proceedings, R.A. Institution," Vol. VIII. p. 261.

on the side of the slope *AB*, *GKO* the trajectory, or path of the projectile in the air, *GV* a tangent to the trajectory at the muzzle; then *GV* represents the line of fire, *GO* the line of sight.

Suppose *POT* a tangent to the trajectory at *O*, the point of impact, *GAT* a horizontal line; then *VGO* is the angle of departure, *PTG* the angle of descent, *VGD* the angle of fire.*

Range. The *range* is the distance from the muzzle of the gun to the second intersection of the trajectory with the line of sight. The range is not accurately the distance to the point at which the projectile impinges on the plane, unless that is also the point aimed at; but the difference is practically of importance only at short distances.†



O is the point aimed at, *STO* the line of sight, *MPO* the trajectory, *TO* the range.

In practice, the range is often taken as the distance from the muzzle of the gun to the first point of impact of the projectile upon the ground; and unless there are great differences in level, it is sufficiently accurate for ordinary purposes.

Terms distinguishing the various natures of artillery fire. The terms distinguishing the various natures of artillery fire have reference (1) to the conditions within the vertical plane, or *plane of fire;* (2) to the conditions within the horizontal or *ground plane.*

(1) The terms denoting the conditions within the vertical plane, or plane of fire, are *direct* fire, *indirect* or *curved* fire, and *high-angle* fire.

Direct fire. *Direct* fire is the fire from guns with service charges at all angles of elevation not exceeding 15°.

Indirect or curved fire. *Indirect* or *curved* fire is the fire from guns with reduced charges, and from howitzers and mortars at all angles of elevation not exceeding 15°.

High-angle fire. *High-angle* fire is the fire from guns, howitzers, and mortars at all angles of elevation exceeding 15°.‡

(2) The terms denoting the conditions within the horizontal or

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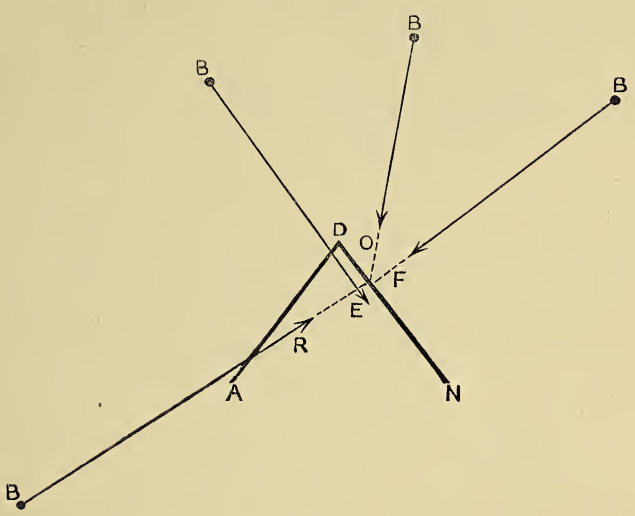
* In the above figure it has been thought simpler to neglect the consideration of the small perpendicular distance between the axis of the bore and the top of the fore sight.

† *Vide* "Proceedings, R.A. Institution," Vol. III. p. 27.

‡ *Vide* Regimental Order dated D.-A.-G.'s Office, 31st January, 1877.

ground plane are *front, oblique, enfilade,* and *reverse* fire. These terms are best explained by means of a diagram.



ADN represents the plan of work fired at, *B* the position of attacking batteries. Then *BF,* perpendicular to the face, *DN,* of the work, represents the general direction of *front* fire; *BO,* oblique to *DN,* represents the general direction of *oblique* fire; *BE,* parallel to the face *DN,* represents the general direction of *enfilade* fire; and *BR,* perpendicular to the reverse slope of *DN,* represents the general direction of *reverse* fire.

Front fire. Oblique fire. Enfilade fire. Reverse fire.

A combination of these terms allows of an accurate description of the precise nature of artillery fire employed; *e.g., direct front* fire denotes that the fire is *direct* in the plane of fire, and *front* in plan, or in the ground plane.

The *deflection* of a projectile is its deviation right or left from the plane of fire at any point of its trajectory, and is measured at any given range by the perpendicular horizontal distance from that plane.

Deflection.

The *muzzle velocity* of a projectile is its velocity at the *muzzle* of the gun.

Muzzle velocity.

Muzzle velocity is generally measured in feet per second (abbreviated thus—"f.s.")

The *resistance of the air* to a projectile in motion, is the force which tends to stop the projectile, and so continually diminishes its velocity. It is generally measured in lbs. avoirdupois.

Resistance of the air.

The *remaining velocity* of a projectile is its velocity at any given point of its trajectory. The remaining velocity of a projectile must in all cases be less than the muzzle velocity, owing to the resistance of the air.

Remaining velocity.

Retardation is the *rate* at which the projectile loses velocity, owing to the resistance of the air.

Retardation.

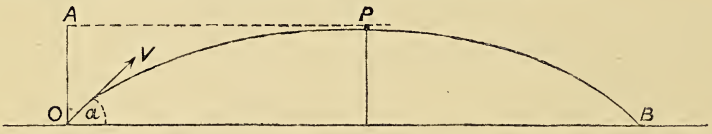
Striking velocity. The *striking velocity* of a projectile is the velocity which it has on impact.

Horizontal velocity. The *horizontal velocity* of a projectile is its velocity at any point resolved in a horizontal direction.

Vertical velocity. The *vertical velocity* of a projectile is its velocity at any point resolved in a vertical direction. Thus, if V be the velocity of a projectile moving at an angle α to the horizon,

$$\text{Horizontal velocity} = V \cos \alpha,$$
$$\text{Vertical } \text{"} = V \sin \alpha.$$

Gravity. *Gravity* is that force (caused by the attraction of the earth) which continually decreases the vertical velocity of the projectile in its ascending path, and then brings the projectile to *rest* in a *vertical* direction. Gravity then causes it to descend, and continually increases its descending vertical velocity till it strikes the ground.



Thus, if OV be the line of fire, α the angle of fire, and V the muzzle velocity of a projectile, its ascending vertical velocity will be

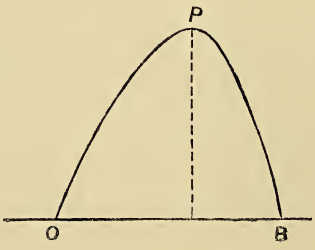
$$V \sin \alpha;$$

or if $V = 650$ f.s., and $\alpha = 30$,

$$\text{ascending vertical velocity} = 650 \times \tfrac{1}{2} = 325 \text{ f.s.}$$

Gravity, and retardation due to the resistance of the air, combine to bring the projectile to rest at some point, A, if it were projected vertically upwards; but owing to the horizontal velocity of the projectile, it will have moved on at the same time to the point P, which is called the vertex, or *maximum height*, of the trajectory. Then the projectile commences to fall, and acquires a *descending vertical velocity* (under the influence of gravity *less* the retardation due to the resistance of the air), which *gradually increases* till the projectile strikes the ground. The horizontal velocity meanwhile has carried the projectile to the point B.

But when a projectile is fired at a high angle of elevation with considerable muzzle velocity, and consequently has a long vertical



distance to fall through in the descending part of the trajectory, there becomes, owing to the resistance of the air (which increases very rapidly as the projectile is acquiring velocity under the action of gravity), a *limit* to the descending vertical velocity which it acquires; so that the descending vertical velocity ceases to increase, and becomes practically uniform.

This limiting vertical velocity is acquired when the *resistance of the air* to the descending projectile in a vertical direction has become equal to the *weight of the projectile;* and it is called the *terminal velocity* —*i.e.*, the maximum descending vertical velocity which a projectile of given weight could acquire on being let fall from any great height. Terminal velocity.

The heavier the projectile, the greater the height it must fall through to attain to its terminal velocity.

The *calibre* of a rifled gun is the diameter of the bore generally measured across the *lands.* Calibre.

In the Armstrong breech-loading system the projectile is made to fit tightly into the grooves, ensuring perfect *centring;* but in all muzzle-loading systems there must be sufficient play between the dimensions of the projectile and those of the bore of the gun to allow of easy loading. This play—or *windage* as it is called—is the difference between the sectional area of the gun through its grooves and that of the body of the projectile through its studs: and is measured practically by the actual linear difference between the calibre of the gun and the diameter of the body of the projectile,* which is called *windage over body;*† also by the linear difference between the diameter through the grooves of the gun and the diameter through the studs of the projectile, which is called *windage over studs;* and also by the linear difference between the width of the groove in the gun and the width of the stud on the projectile, which is called the *play of the stud.* Windage.

Clearance is the linear distance between the body of the projectile and the bore of the gun. The amount of clearance before the projectile moves is the difference between the depth of the groove in the gun and the projection of the stud on the projectile; but when the projectile is in motion and centred in the bore, the clearance all round the projectile will be half the windage over body. Clearance.

It is very important to reduce the windage as much as possible consistently with ease and rapidity of loading, in order to obtain accuracy of fire; but, on the other hand, it is most important that the projectile should not *jam* in loading. Sufficient windage‡ should therefore be given to render a jam improbable under ordinary conditions of service.

All projectiles are gauged before issue into the service, by passing over them hollow cylinder gauges smaller than the calibre of the gun; and all guns are gauged by a solid, cylindrical, studded plug, larger than the projectile, so as to ensure sufficient limits for easy loading. By this system of gauging, all manufacturing errors liable to cause a jam are detected and rectified.

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* See "Treatise on Ammunition," p. 140.

† With projectiles having a copper cup attached to their base, to give the necessary rotation *without studs*, the windage is simply measured by the linear difference between the calibre of the gun and the diameter of the projectile.

‡ See "Treatise on Ammunition," p. 210.

But, on service, studs on the projectile are liable to be set up and to corrode; also the gun becomes foul from continued firing; so that a certain fixed amount of windage is absolutely necessary, both over the body and over the studs. The dimensions of the hollow cylinder gauge and the solid plug gauge are adjusted accordingly, so as to ensure the requisite amount of windage being given which has been found practically necessary for the ordinary conditions of service.

Disadvantages of windage.

There are certain disadvantages in having windage which it has been the object of artillerists to nullify, or mitigate as much as possible. They are :—

(1) Loss of powder gas, which escapes by the windage without increasing the velocity of the projectile.

(2) The scoring, or guttering effect which this rush of gas has on the bore of the gun, after a few rounds are fired. In the larger nature of guns, this scoring becomes of serious importance: the upper portion of the bore—where the rush is greatest—becoming excessively scored, rendering the gun unserviceable.

(3) The compression of the studs upon which the weight of the projectile rests when rammed home, owing to the great pressure caused by the rush of gas over the projectile at the first instant of discharge. In some cases, the lower studs—*i.e.*, the studs which bear the weight of the projectile—become so compressed that the clearance is abolished, and the body of the projectile comes into contact with the grooves of the gun; thus tending to strain inordinately both the projectile and the gun. When this has been the case, an examination of the recovered projectile usually shows the marks of the groove of the gun on its body.

(4) The liability to non-centring, and so diminishing the range and accuracy of the gun.

These disadvantages have to a great extent been obviated in the larger nature of guns by the employment of a copper gas-check at the base of the projectile, which is expanded into the grooves of the gun, &c., by the shock of discharge; so that the projectile is centred and the windage sealed.

Windage is useful in the M.L. guns, as it allows the rush of heated gas over the projectile at the moment of explosion to ignite the quick-match in the time fuze, and to set it in action; but with reduced charges, such as are used in *indirect* or *curved fire*, the heat developed is not sufficient to ensure the ignition of the quickmatch. The fuze in such cases is wrapped round with a strand of gun-cotton, to make ignition certain.*

On the other hand, with percussion fuzes having safety-pins (such as the Royal Laboratory percussion fuze), which are withdrawn when the fuze is fixed in the shell, some arrangement must be made to prevent the heated gas penetrating through the hole thus made, and so causing premature explosion.

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* See "Treatise on Ammunition," p. 18.

CHAPTER II.

Terms used in Gunnery.

(*Continued.*)

Rifling.—Angle of Spiral.—Twist of Rifling.—Relation between Angle of Spiral and Twist of Rifling.—Determination of the Twist of Rifling at any point in the Bore.—Determination of Linear Rotation of the Exterior of the Projectile, while passing down the Bore.—Examination of recovered Projectiles for groove-marks on Body and Studs.—The Motion of Translation and Rotation of a Projectile fired from Rifled Ordnance.—Velocity of Translation.—Velocity of Rotation.—Linear Velocity of Rotation.—Work.—Pressure per square inch on the Bore of the Gun.—Work Done per square inch.—Energy.—Energy per inch of Circumference.—Energy due to Translation.—Energy due to Rotation.—Total Energy.—Pressure required to give Rotation to Projectiles.—Velocity of Recoil.—Gun Pendulum.—Experiments on Recoil.—Energy of Recoil.—How the Energy of Recoil may be Reduced.—Kemmis's Table of Service M.L.R. Ordnance.

Rifling.

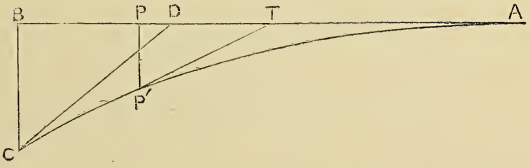
All rifled guns have grooves cut spirally in the bore, in order to give the projectile rotation round its longer axis.

Angle of spiral.

The angle of spiral (or angle of rifling) differs in different guns, depending principally on the length, weight, and muzzle velocities of the projectiles fired from them.

It is measured at any point of the groove, in guns rifled with *increasing twist* by the angle which a tangent to the groove at that point makes with a line in the bore parallel to its axis; and in guns rifled with *uniform twist*, by the angle which the groove itself makes with a line in the bore parallel to its axis.

Suppose AB to represent the length of the rifled part of the bore of a gun rifled with increasing twist, AC the groove with increasing twist, AB the direction of the axis of the bore—A at the breech end, B at the muzzle.



Then the angle of spiral at the point P' of the groove (corresponding to P in the axis of the bore) is measured by the angle $P'TB$, where $P'T$ is a tangent to the curve at the point P'. In guns rifled with increasing twist, the angle of spiral at the muzzle is called the *final angle of rifling* and that at the breech end of the rifling is called the *initial angle of rifling*. PP' and BC represent the linear distances through which the exterior of the projectile has rotated when it has arrived at the points P and B in the axis of the bore respectively.

Twist of rifling.

The *twist of rifling*, with *uniform* twist, is estimated by the distance (generally expressed in calibres) in which the spiral makes *one turn*;

with the *increasing* twist, it is estimated at any point by the distance in which the spiral would make *one turn* had the angle of spiral remained uniform, and the same as at the given point.

Relation between angle of spiral and twist of rifling.

Suppose α the angle of spiral at any point in the bore; also suppose the twist of rifling at the same point to be one turn in n calibres. Then

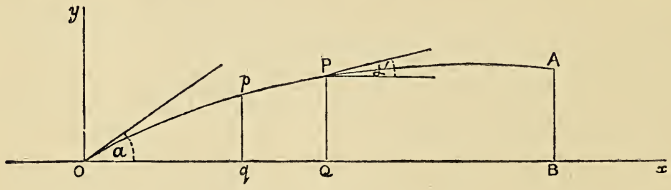
$$\tan \alpha = \frac{\pi}{n};^*$$

which expresses the relation between the angle of spiral and twist of rifling at any point in the bore.

Determination of the twist of rifling at any point in the bore.

PROBLEM.—To find the twist at any point of the bore of a gun rifled with increasing twist.

Let α and α' be the angles of spiral at the muzzle and at the breech respectively; n and m the number of calibres in which the spiral makes one turn at the muzzle and at the breech respectively.



In the figure, OP represents the curve (increasing twist)—O at the muzzle and P at the breech end of the rifling. The curve OP is a parabola, whose vertex is at A; and is referred to vertical and horizontal co-ordinates, whose origin is at O. Then

$$\tan \alpha = \frac{\pi}{n}, \text{ and } \tan \alpha' = \frac{\pi}{m}.$$

Let $y = bx + cx^2$ be the equation to the curve.

Differentiating,

$$\frac{dy}{dx} = b + 2cx; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where $x = 0$, $\frac{dy}{dx} = \tan \alpha = b$.

Let OQ (the length of rifling in the bore) $= l$. Then from equation (1)

$$\tan \alpha' = \tan \alpha + 2cl;$$

or

$$2c = \frac{\tan \alpha' - \tan \alpha}{l} = \frac{\frac{\pi}{m} - \frac{\pi}{n}}{l}.$$

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* See "Treatise on the Construction and Manufacture of Ordnance in the British Service," p. 41.

Let $Oq = h$, and ϕ the angle of spiral at p. Then from equation (1)

$$\tan \phi = \tan \alpha + 2ch$$

$$= \frac{\pi}{n} + \frac{h\left(\frac{\pi}{m} - \frac{\pi}{n}\right)}{l} = \frac{\pi}{n}\left\{1 + \frac{h}{l}\left(\frac{n}{m} - 1\right)\right\}.$$

Therefore twist of rifling at the point p is

$$\text{one turn in } \frac{n}{1 + \frac{h}{l}\left(\frac{n}{m} - 1\right)} \text{ calibres. .....(A)}$$

For example: in the 12-in. gun of 25 tons, the twist at the muzzle is one turn in 50 calibres; that at the breech is one turn in 100 calibres. The length of rifling is 127 ins. It is required to find the twist in calibres at 8 ins. from the muzzle.

Here $n = 50$,
$m = 100$,
$l = 127$ ins.
$h = 8$ ins.

Then, substituting in the above formula (A), the twist at 8 ins. from the muzzle is

$$\text{one turn in } \frac{50}{1 + \frac{8}{127}\left(\frac{50}{100} - 1\right)} = 51{\cdot}626 \text{ calibres.}$$

Next, to find the linear distance the exterior of the projectile has rotated while passing down the bore.

Determination of linear rotation of exterior of projectile, while passing down the bore.

Suppose $Oq = h$ (the distance passed down the bore by the projectile); then

$$pq = bh + ch^2 = h \tan \alpha + h^2 \frac{\tan \alpha}{2l} - \tan \alpha$$

$$= \frac{\pi h}{n} + \frac{\pi\left(\frac{1}{m} - \frac{1}{n}\right)h^2}{2l}. \text{ .....(B)}$$

For example: it is required to find the linear distance which the exterior of the projectile has rotated in the 12-in. gun of 25 tons, when it has passed down 8 ins. of the bore from the muzzle.

In equation (B),

$$h = 8 \text{ ins.}$$

and substituting as before, the linear distance of rotation of the exterior of the projectile at 8 ins. from the muzzle is

$$\frac{8\pi}{50} + \frac{\pi\left(\frac{1}{100} - \frac{1}{50}\right)}{254} \times 64 = \frac{4000\pi}{25400} = {\cdot}49 \text{ ins.}$$

In several Woolwich guns the twist is zero at the breech end of the rifling; so that in this case

$$\tan \alpha' = \frac{\pi}{m} = 0, \text{ or } \frac{1}{m} = 0.$$

So that from equation (A) the twist of rifling at a point in the bore at h inches from the muzzle is

$$\text{one turn in } \frac{n}{1 - \frac{h}{l}} = \frac{nl}{l - h} \text{ calibres;} \quad \ldots\ldots\ldots\ldots\ldots\ldots (C)$$

and from equation (B) the linear distance of rotation of the exterior of the projectile at a distance of h inches down the bore is

$$\frac{\pi h}{n} - \frac{\pi h^2}{2nl} = \frac{\pi h}{n}\left(1 - \frac{h}{2l}\right). \quad \ldots\ldots\ldots\ldots\ldots\ldots (D)$$

Examination of recovered projectiles for groove-marks on body and studs.

It is often important, when examining projectiles which have been recovered after firing, to note the marks of the grooves on their bodies and studs, in order to determine the exact position in the bore of the gun where these marks were impressed.

For example: an 11-in. common shell, after having been fired, was recovered and examined for marks of the grooves on the driving edges of the studs. The impression on the front stud was due to a twist of one turn in 385 ins., or one turn in 35 calibres—the same as at the muzzle of the gun; showing that the front stud was in *bearing* at the muzzle. The impression on the rear stud was due to a twist of one turn in 592 ins., or one turn in 53·8 calibres; and the impression of the groove marks on the body of the shell (owing to contact of the body of the shell with the gun, from defective centring), was due to a twist of one turn in 1584 ins., or one turn in 144 calibres.

From these data it can be ascertained at what distance from the muzzle the *rear* stud ceased to rotate the projectile, and the front stud came into bearing; and also at what distance from the muzzle the shell must have been when there was contact between the body of the shell and the bore of the gun.

The length of rifling in the 11-in. M.L. gun is 119 ins., and the twist starts from zero at the breech to one turn in 35 calibres at the muzzle.

The amount of twist shown at the last contact of the rear stud with the side of the groove was one turn in 53·8 calibres.

From formula (C)

$$\frac{nl}{l - h} = 53{\cdot}8 \text{ (where } l = 119 \text{ and } n = 35),$$

$$\text{or } 53{\cdot}8h = 2237{\cdot}2,$$

$$\text{or } h = 41{\cdot}5 \text{ ins. from the muzzle;}$$

which shows that the front stud came into bearing at 41·5 ins. from the muzzle.

In the same way, the place of contact between the body of the shell and the lands of the gun can be found. In this case

$$\frac{nl}{l-h} = 144,$$

or $h = 90{\cdot}07$ ins. from the muzzle;

i.e., 28·93 ins. from the breech end of rifling.

The motion of translation and rotation of a projectile fired from rifled ordnance.

When the motion of projectiles fired from rifled ordnance comes under consideration, it is necessary to distinguish between the *motion of translation* and the *motion of rotation*.

Motion of translation refers to the motion of a projectile travelling through the air; the motion of rotation to its spinning round its longer axis.

Both these motions are combined in the motion of an elongated projectile fired from rifled ordnance; but they are quite independent of one another, and may be considered separately.

Velocity of translation.

The *velocity of translation* of a projectile is usually measured by its *linear* velocity in feet per second.

Velocity of rotation.

The *velocity of rotation* of a projectile is usually measured by its *angular* velocity in units of circular measure per second. The angular velocity of a projectile making *one turn* in one second is 2π.

Now, if ω be the angular velocity of a projectile per second, and s the *number of turns* it makes in a second, then

$$s = \frac{\omega}{2\pi}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

i.e., the number of revolutions per second is proportional to the *angular velocity*.

Also, if the projectile makes *one revolution* in n calibres—*i.e.*, in nd inches, where d is the calibre of the gun in inches, and V the muzzle velocity in feet per second—then the number of revolutions of the projectile per second as it leaves the muzzle of the gun is

$$s = \frac{12V}{nd}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Equating (1) and (2), it will be seen that

$$\omega = \frac{24\pi V}{nd}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

or the angular velocity of a projectile is directly proportional to the muzzle velocity, and inversely proportional to the length of twist.

Linear velocity of rotation.

The linear velocity of rotation of any point in a rotating projectile is the *product* of its angular velocity into the distance of that point from the axis of rotation; or if ω be the angular velocity, and r the distance of the point from its axis of rotation in inches,

$$\text{linear velocity of rotation} = \omega r = \frac{2\pi Vr}{nd} \text{ in feet per second.}$$

Example.—To find the number of revolutions per second, the angular velocity, &c., of the 16-pr. shell at the muzzle. The muzzle velocity

of 16-pr. = 1358 f.s., calibre 3·6 ins., twist 1 turn in 30 calibres. From (2),

$$\text{number of revolutions per second} = \frac{12 \times 1358}{108} = 150{\cdot}9\,;$$

and from (3),

$$\text{angular velocity} = 2\pi \times 150{\cdot}9 = 301{\cdot}8\pi = 948{\cdot}1.$$

Also, linear velocity of rotation of a point on the surface of the projectile is

$$948{\cdot}1 \times 1{\cdot}77 = 1678{\cdot}2 \text{ ins. per second,}$$

since diameter of shell is 3·54 ins.; or, expressing the velocity in feet per second, the linear velocity of rotation of the 16-pr. shell

$$= \frac{1678{\cdot}2}{12} = 139{\cdot}8 \text{ ft. per second.}$$

Work.

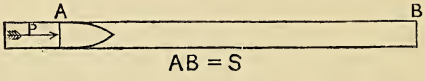
Work.—When a projectile has been set in motion from rest, some force or pressure must have been exerted upon it. This force or pressure is then said to have done *work;* and the amount of *work done* is measured by the product of the *pressure* into the *distance* through which the projectile has been moved. Work done is usually expressed in foot lbs., although for artillery purposes it is often expressed in foot tons.

Thus, if P be the pressure in lbs. exerted on a projectile through the space of S feet, then the work done on the projectile is

$$P \times S \text{ ft. lbs.} = \frac{PS}{2240} \text{ ft. tons.}$$

But, in practice, the pressure exerted on a projectile during its passage through the bore of a gun is not constant but *variable;* so that to obtain the approximate amount of work done, the product of the *mean pressure* on the projectile into its *distance* moved through the bore of the gun must be taken. Then

P = mean pressure on projectile
= mean pressure on the bore of the gun.



Example.—If the total mean pressure on the base of a Palliser shell, fired with a battering charge out of the 10-in. M.L. gun, were 516 tons, what would be the work done on the shell at the muzzle?

The distance through which the pressure acts must be the difference between the length of the bore and the length of the cartridge.

Length of bore of 10-in. M.L. gun is 145·5 ins.
Mean length of cartridge..... " 25·5 "

The difference will be the distance passed over by the shell from its seat to the muzzle—viz., 120 ins. = 10 ft.; consequently, work done = 10 × 516 = 5160 ft. tons.

Pressure per square inch on the bore of the gun.

It is often convenient to express the pressure exerted on the bore of the gun in terms of the number of *square inches* in its sectional area, by

dividing the mean pressure by the number of square inches in its sectional area. Thus

$$p = \text{pressure per square inch} = \frac{\text{mean pressure}}{\pi \cdot \frac{d^2}{4}} = \frac{P}{\cdot 7854 d^2};$$

where d is the diameter of the bore in inches.

Work done per square inch.

Similarly,

$$\text{work done per square inch} = \frac{\text{total work done}}{\cdot 7854 d^2} = \frac{PS}{\cdot 7854 d^2}.$$

Energy.

When a projectile is in motion, it is said to have *energy—i.e.*, it is capable of doing work, or overcoming resistance. The amount of energy is measured by the *product of the weight of the projectile into the height due to its velocity*, and is expressed in the same units as those of work done.

Thus, if W be the weight of the projectile in lbs., h the height it would require in vacuo to attain a velocity v in feet per second, then the energy of the projectile is

$$Wh = \frac{Wv^2}{2g} \text{ ft. lbs.};$$

where $h = \frac{v^2}{2g}$.*

Now, if V be the muzzle velocity of the projectile, its energy at the muzzle of the gun is $\frac{WV^2}{2g}$; and since the energy of the projectile is equivalent to the work done on it,

$$E = \frac{WV^2}{2g} = PS;$$

where E represents the energy at muzzle.

It will therefore be seen that the energy of the projectile at the *muzzle* is equal to the work done by the pressure of the powder gas in the bore of the gun.

Example.—Find the energy of the 10-in. M.L. gun at the muzzle, firing Palliser shell with a battering charge. Weight of shell = 400 lbs., muzzle velocity = 1364 f.s.

$$\text{Energy at muzzle} = \frac{400 \times (1364)^2}{2 \times 32{\cdot}19} \text{ ft. lbs.}$$

$$= \frac{400 \times (1364)^2}{2 \times 32{\cdot}19 \times 2240} \text{ ft. tons} = 5160 \text{ ft. tons.}$$

i.e., if a uniform resistance of 5160 tons were opposed to the shell, it would penetrate *one foot* before it was brought to rest; or if the resistance were 516 tons, it would penetrate 10 ft., and so on.

Energy per inch of circumference.

In order to estimate the comparative power of guns for piercing iron plates, it is usual to express the energy of a projectile in terms of

* See "Treatise on Dynamics,"—Motion of a Particle falling freely in vacuo.

the number of inches in its circumference—*i.e.*, by dividing the energy by the number of inches in the circumference of the projectile. Thus,

$$\text{energy per inch of circumference} = \frac{Wv^2}{4480g \times \pi d} \text{ ft. tons};$$

where d is the diameter of the projectile in inches.

Also, $$\text{energy per inch of circumference at muzzle} = \frac{E}{\pi d} = \frac{WV^2}{4480g \times \pi d};$$

thus, muzzle energy per inch of circumference of 10-in. Palliser shell

$$= \frac{5160}{3{\cdot}1416 \times 9{\cdot}92} = 165{\cdot}6 \text{ ft. tons.}$$

Energy due to translation.

This energy is energy due to the velocity of translation of the projectile. But the projectile has rotation round its longer axis; so that there is also energy due to the velocity of rotation, which, being small as compared to the energy due to translation, is usually neglected.

Energy due to rotation.

But in considering the rotation of projectiles, the energy due to rotation must also be taken into account.

If ω represent the angular velocity of the projectile, K its radius of gyration in feet, then

$$\text{energy due to rotation} = \frac{W(K\omega)^2}{2g}.$$

Total energy.

The *total energy* of a rifled projectile in motion

$$= \text{energy due to translation} + \text{energy due to rotation}$$

$$= \frac{W}{2g}v^2 + \frac{W}{2g}(K\omega)^2 = \frac{W}{2g}\{v^2 + (K\omega)^2\};$$

where W = weight of projectile and v its velocity.*

---

* If V be the muzzle velocity, and ω the muzzle angular velocity, then

$$\text{total energy of projectile at muzzle} = \frac{W}{2g}(V^2 + K^2\omega^2);$$

but $$\omega = \frac{24\pi V}{nd} \text{ (see p. 37)},$$

and $$K = \frac{k}{12},$$

where k = radius of gyration in inches.

$$\therefore \text{ total energy at muzzle} = \frac{WV^2}{2g}\left\{1 + \left(\frac{2\pi}{nd}\right)^2 k^2\right\};$$

where n = twist of rifling in calibres, and d = diameter of projectile in inches.

It can be shown that the moment of inertia $\left(\frac{W}{g}k^2\right)$ of the head of a solid projectile with an ogival head of $1\frac{1}{2}$ diameters

$$= \pi\rho d^5 \times {\cdot}015189, \quad \ldots\ldots(A)$$

or $$Mk^2 = \pi\rho d^5 \times {\cdot}015189;$$

where ρ is the density of the projectile, M is the mass of the projectile, and d its diameter.

Also, that the *volume* of the *ogival head*

$$= \pi d^3 \times {\cdot}15733. \quad \ldots\ldots(B)$$

EXAMPLE.—*To find moment of inertia of* 16-*pr. common shell* (*vide Changes in War Stores*, §2190):—

Ogival head. 1st. Suppose solid.

(1) Body. $M_1k_1^2 = \pi\rho d^5 \times {\cdot}01519 = \pi\rho\,(3{\cdot}54)^5 \times {\cdot}01519 = 8{\cdot}443 \times \pi\rho.$

(2) $M_2k_2^2 = \pi\rho\frac{d^4}{2^5} \times \text{length} = \pi\rho\frac{(3{\cdot}54)^4}{2^5} \times 6{\cdot}9 = 33{\cdot}87 \times \pi\rho.$

$\therefore$ total moment of inertia of solid projectile $= M_1k_1^2 + M_2k_2^2 = 42{\cdot}31\pi\rho.$ .....(1)

It must be remembered that the velocity of translation is given by the pressure of the powder gas on the base of the projectile, and that the velocity of rotation is given by the pressure of the sides of the grooves against the driving edges of the studs of the projectile, as it travels through the bore.

Pressure required to give rotation to projectiles.

The pressure on the driving edges of the studs depends on the angle of spiral in the gun, and also on the employment either of uniform or increasing twist, in order to give the requisite rotation to the projectile.

To compute moment of inertia of the core :—

(1) Head. $m_1K_1^2 = \pi\rho\,(2{\cdot}34)^5 \times {\cdot}01519 = 1{\cdot}065\pi\rho,$

(2) Body. $m_2K_2^2 = \pi\rho\,\dfrac{(2{\cdot}34)^4}{2^5} \times 6{\cdot}04 = 5{\cdot}659\pi\rho;$

$\therefore$ total moment of inertia of core $= m_1K_1^2 + m_2K_2^2 = 6{\cdot}724\pi\rho;$ .....(2)

$\therefore$ moment of inertia of empty shell $= 42{\cdot}31\pi\rho - 6{\cdot}724\pi\rho = 35{\cdot}59\pi\rho.$ .....(3)

If the shell is filled with water (the density of which does not differ greatly from that of the powder in a filled shell), then for the core, the density $\rho = 1$, and for the cast-iron shell $\rho = 7{\cdot}11$.

Therefore from (3),

moment of inertia of empty shell $= 35{\cdot}59 \times 7{\cdot}11\pi = 253{\cdot}0\pi,$

and from (2), " core filled with water $= 6{\cdot}7\pi,$

$\therefore$ total moment of inertia of filled shell $= 259{\cdot}7\pi.$ .....(4)

To find the radius of gyration of filled 16*-pr. common shell :—*

1st. Suppose solid.

(1) Ogival head. The volume of ogival head, or $\dfrac{M_1}{\rho} = \pi d^3 \times {\cdot}1573;$

$\therefore M_1 = \pi\rho d^3 \times {\cdot}1573 = \pi\rho\,(3{\cdot}54)^3 \times {\cdot}1573 = 6{\cdot}977\pi\rho.$

(2) Body. $M_2 = \pi\rho\left(\dfrac{d}{2}\right)^2 \times \text{length} = \pi\rho\left(\dfrac{3{\cdot}54}{2}\right)^2 \times 6{\cdot}9 = 21{\cdot}62\pi\rho.$

$\therefore M_1 + M_2 = 28{\cdot}60\pi\rho.$

2nd. To find $m_1 + m_2$ of core.

(1) Head. $m_1 = \pi\rho\,(2{\cdot}34)^3 \times {\cdot}1573 = 2{\cdot}015\pi\rho.$

(2) Body. $m_2 = \pi\rho\,(1{\cdot}17)^2 \times 6{\cdot}04 = 8{\cdot}268\pi\rho.$

$\therefore m_1 + m_2 = 10{\cdot}28\pi\rho.$

$\therefore$ mass of empty shell $= (28{\cdot}60 - 10{\cdot}28)\,\pi\rho = 18{\cdot}32\pi\rho$

$= 18{\cdot}32 \times 7{\cdot}11\pi = 130{\cdot}3\pi$ (since $\rho = 7{\cdot}11$),

mass of filled core $= 10{\cdot}28\pi$ (since $\rho = 1$),

$\therefore$ " filled shell $= (130{\cdot}3 + 10{\cdot}28)\pi = 140{\cdot}58\pi,$

$\therefore k^2 = \dfrac{\text{moment of inertia of filled shell}}{\text{mass of filled shell.}} = \dfrac{259{\cdot}7\pi}{140{\cdot}6\pi} = 1{\cdot}848$ ins.,

$\therefore k = \sqrt{1{\cdot}848} = 1{\cdot}35$ ins.;

where k is the radius of gyration of the filled shell.

Now, if the muzzle velocity of a filled 16-pr. common shell, fired with a service charge of 3 lbs. R.L.G. powder, is 1358 ft. per second, and weight of filled shell = 15 lbs. 13 ozs., the total energy at muzzle, or total work done by 3 lbs. of powder

$$= \frac{WV^2}{2g}\left\{1 + \left(\frac{2\pi}{nd}\right)^2 k^2\right\} = \frac{15{\cdot}81 \times (1358)^2}{2 \times 32{\cdot}19 \times 2240}\left\{1 + \left(\frac{2 \times 3{\cdot}1416}{30 \times 3{\cdot}54}\right)^2 1{\cdot}848\right\} \text{ ft. tons}$$

$= 202{\cdot}2\,(1 + {\cdot}001894)$ ft. tons $= 202{\cdot}2 \times 1{\cdot}0019 = 202{\cdot}6$ ft. tons.

$\therefore$ work done by each lb. of powder in the charge $= \dfrac{202{\cdot}6}{3} = 67{\cdot}5$ ft. tons.

Since the work done in rotating the projectile is such a small per-centage of the work done in giving velocity, the former is usually neglected in calculations for penetration of iron plates, &c.

Captain Andrew Noble, of Elswick, has calculated the total pressure on the base and also on the studs of a 10-in. shell fired with a charge of 70 lbs. of pebble powder, in the case of the gun being rifled (1) with uniform twist, or (2) with increasing twist.*

The uniform twist is taken at one turn in 40 calibres; and the increasing twist commences with one turn in 100 calibres, and terminates at the muzzle with one turn in 40 calibres—the same as the uniform twist at the muzzle; so that the shell, while moving with the same velocity at the muzzle, would have the same muzzle velocity of rotation in both cases.

Travel of shell.	Total pressure on base of shell in both cases.	Corresponding velocity in both cases.	Total pressure on studs.	
			Uniform twist. (1)	Increasing twist. (2)
ft.	tons.	f.s.	tons.	tons.
·000	0	0	0·0	0·0
·333	1547	411	68·5	31·2
·945	1077	675	47·7	28·7
1·834	781	873	34·6	29·0
2·723	621	992	27·5	30·2
3·612	510	1078	22·6	31·4
4·500	424	1146	18·7	32·3
5·389	356	1200	15·8	33·0
6·278	305	1245	13·5	33·8
7·167	268	1282	11·8	34·5
8·055	240	1311	10·6	35·2
8·944	220	1333	9·7	35·8
9·833	205	1349	9·1	36·3

It appears from this table that the pressure on the studs at the commencement of motion is much less in the increasing than in the uniform twist, and consequently that the studs on the projectile would not be so severely strained, nor the driving sides of the grooves of the gun so much indented in the increasing as in the uniform twist. This is what is found to be the case in practice, and is the reason why the increasing twist has been preferred to the uniform twist for the heavier natures of guns.

Velocity of recoil.

The *velocity of recoil* is generally taken as the velocity imparted to the gun and carriage by the discharge of the piece. It is the greatest when the projectile leaves the muzzle.

Let V'' be the maximum velocity of recoil,
v the muzzle velocity of projectile,
w the weight of projectile,
w' the weight of charge of powder,
W'' the weight of gun and carriage.

Then, if the momentum of the gun and carriage be taken equal to the momentum of the projectile,

$$W''V'' = (w + Cw')\,v,$$

$$\text{or } V'' = \frac{(w + Cw')\,v}{W''}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

* See "Proceedings, R.A. Institution," Vol. VIII. p. 365.

where C is a coefficient varying in different guns, which may be determined by experiment.

But this formula is not strictly correct, for three reasons:—

(1) On account of the difference between the sectional areas of the projectile and of the bore of the gun when there is *windage*.

(2) On account of the uncertainty of the amount of momentum communicated to the gun by the motion of the centre of gravity of the powder charge.

(3) On account of the small additional momentum communicated to the gun after the projectile has left the muzzle.

Since the sectional areas of the bore and projectile are as the squares of their diameters, if d be the diameter of the projectile and D that of the bore, the momentum communicated to the gun will be $\frac{D^2}{d^2} wv$; and if the small additional momentum communicated to the gun and carriage after the projectile has left the muzzle be expressed by $W''V'$, and if $Cw'v$ be the amount of momentum communicated to the gun and carriage by the motion of the centre of gravity of the powder charge, then

$$W''V'' = \frac{w}{d^2} D^2 v + Cw'v + W''V'. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Gun pendulum.

It is the uncertainty of these terms that makes the measurement of muzzle velocities by means of the *gun pendulum* so inaccurate; but the instrument is well adapted to measure the velocity of recoil.

The gun pendulum consists of a frame in which a light gun is suspended by means of a rod. The pendulum, of which the gun forms the *bob* is capable of moving freely when the gun is fired. An arc graduated in degrees and minutes is attached to the frame, by means of which the angle of recoil is registered.

Great care is necessary, in adjusting the weights, to get the centre of percussion very nearly in the axis of the bore.*

Experiments on recoil.

Some experiments with a gun pendulum were made at the Royal Laboratory, Woolwich, in 1874, to determine the recoil of the Martini-Henry and Snider rifles. The rifles were alternately fixed in the pendulum with their barrels horizontal and weighted up to the same weight, and so adjusted that the centre of percussion was very nearly in the axis of their barrels. They were fired by means of a hair trigger, so as to avoid communicating any sensible motion to the pendulum in firing. The angle of recoil was then read off, and the mean angle of five rounds recorded, and the work done on the pendulum by the discharge of the rifle computed, and thence the work done in recoil. (See the following table.)

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* See Boxer's "Treatise on Artillery," p. 36.

Nature of rifle.	Weight of rifle.	Nature of powder.	Charge of powder.	Weight of bullet.	Muzzle velocity.	Work done in recoil.*
	lbs.		grs.	grs.	f.s.	ft.lbs.
Martini-Henry...	8·81	R.F.G.^{2}	85	480	1303	19·07
" ...	8·81	C. & H.	80	410	1380	15·43
Snider	8·95	R.F.G.	70	480	1248	16·39

* As determined by experiment with gun pendulum.

The muzzle velocities were taken by means of Professor Bashforth's gravity chronograph, and are all below the average, as they were taken in the winter, at the same time as the experiments on the recoil. The recoil of the Martini-Henry rifle with the service cartridge is 19·07 ft. lbs.; in other words, the recoil of the rifle would exert a steady pressure on the shoulder of 19·07 lbs. through the *space of one foot,* or $2 \times 19{\cdot}07 = 38{\cdot}14$ lbs. through the space of half a foot; or generally $n \times 19{\cdot}07$ lbs. through the space of $\frac{1}{n}^{\text{th}}$ of a foot—the intensity of the blow on the shoulder for the same amount of recoil depending on the skill of the man in firing.

In these experiments, as there is no windage, the error due to windage disappears; the small additional momentum communicated to the rifle after the bullet has left the muzzle may also be neglected; so that equation (1) may be used without sensible error, or

$$W''V'' = (w + Cw')\,v,$$

$$\text{or } V'' = \frac{(w + Cw')\,v}{W''}.$$

Energy of recoil.

Now, the *energy of recoil* (which it must be remembered is entirely different from the momentum communicated by the discharge of the piece) is $\frac{W''V''^2}{2g}$; or, substituting for V'' its value,

$$\text{energy of recoil (or work done in recoil)} = \frac{W''V''^2}{2g} = \frac{W''}{2g}\left(\frac{w + Cw'}{W''}\right)^2 v^2;$$

and if the weight of the charge is $\frac{1}{n}^{\text{th}}$ the weight of the projectile,

$$w' = \frac{w}{n};$$

$$\text{energy of recoil (or work done in recoil)} = \frac{wv^2}{2g} \cdot \frac{w}{W''}\left(1 + \frac{C}{n}\right)^2. \quad \ldots\ldots(3)$$

The coefficient C varies with the nature of ordnance or small-arm, system of rifling, and also with the powder employed; but for the *same* description of gun or rifle fired under the *same* general conditions, the coefficient C may be taken as practically constant.

In the above experiments with the Martini-Henry rifle $C = {\cdot}96$; and with the Snider $C = {\cdot}75$.

NS,

Nature.	$= P$.	Average pressure per sq. in., $= p$.	$\frac{W}{p}$	Carriage. Weight, $= W'$	$\frac{W'}{P}$	$\frac{W}{W'}$	Gun and Carriage. Weight, $= W''$.	Velocity of recoil, $= V''$.	Work done upon. $= \frac{W''.V''^2}{2g}$	Nature.	
		lbs.		lbs.			lbs.	ft. secs.	ft. lbs.		
7-pr. of 200 l	0	6,697	$\frac{1}{33\cdot48}$	350	$\frac{1}{135\cdot20}$	$\frac{1}{1\cdot75}$	550	14·31	1,749	7-pr. of 200 lbs. (steel).	FIELD.
9-pr. of 6 cw	0	9,705	$\frac{1}{14\cdot44}$	1,280	$\frac{1}{53\cdot58}$	$\frac{1}{1\cdot90}$	2,049[j]	7·33	1,711	9-pr. of 6 cwt.	
9-pr. of 8 cw	0	10,130	$\frac{1}{14\cdot23}$	1,280	$\frac{1}{55\cdot93}$	$\frac{1}{1\cdot42}$	2,273[j]	6·60	1,538	9-pr. of 8 cwt.	
16-pr. of 12 c	0	10,730	$\frac{1}{9\cdot55}$	1,431	$\frac{1}{76\cdot26}$	$\frac{1}{1\cdot06}$	2,896[j]	8·86	3,534	16-pr. of 12 cwt.	
25-pr. of 18 c	0	9,109	$\frac{1}{4\cdot52}$	1,700	$\frac{1}{67\cdot33}$	$\frac{1}{\cdot84}$	3,755[j]	9·86	5,671	25-pr. of 18 cwt.	
40-pr. of 34 c	0	11,090	$\frac{1}{2\cdot91}$	3,460	$\frac{1}{56\cdot78}$	$\frac{1}{\cdot90}$	7,268	8·02	7,263	40-pr. of 34 cwt.	
40-pr. of 35 c	0	8,857	$\frac{1}{2\cdot25}$	3,460	$\frac{1}{45\cdot34}$	$\frac{1}{\cdot88}$	7,380	7·94	7,228	40-pr. of 35 cwt.	
64-pr. of 64 c	0	11,480	$\frac{1}{1\cdot60}$	3,715	$\frac{1}{96\cdot34}$	$\frac{1}{\cdot51}$	10,883	10·17	17,500	64-pr. of 64 cwt.	
6·3-in. howr. c	0	6,751	$\frac{1}{1\cdot35}$	3,480	$\frac{1}{60\cdot46}$	$\frac{1}{1\cdot72}$	5,496	9·70	8,028	6·3-in. howr. of 18 cwt.[a]	
8·0-in. howr.	0	11,320	$\frac{1}{2\cdot19}$	4,802	$\frac{1}{118\cdot40}$	$\frac{1}{\cdot93}$	9,954	15·13	35,390	8·0-in. howr. of 46 cwt.	
64-pr. of 58 c	0	6,757	$\frac{1}{1\cdot04}$	1,232[d]	$\frac{1}{170\cdot40}$	$\frac{1}{\cdot19}$	7,728	11·60	16,140	64-pr. of 58 cwt.	GARRISON AND NAVAL.
64-pr. of 71 c	0	6,947	$\frac{1}{\cdot87}$	1,596[e]	$\frac{1}{135\cdot20}$	$\frac{1}{\cdot20}$	9,548	9·27	12,760	64-pr. of 71 cwt.	
64-pr. of 64 c	0	9,942	$\frac{1}{1\cdot37}$	1,326[f]	$\frac{1}{231\cdot40}$	$\frac{1}{\cdot18}$	8,494	12·05	19,150	64-pr. of 64 cwt.	
80-pr. of 5 to	0	8,145	$\frac{1}{\cdot72}$	1,568[d]	$\frac{1}{161\cdot40}$	$\frac{1}{\cdot14}$	12,768	8·73	15,110	80-pr. of 5 tons.	
7-in. of 90 cw	0	10,190	$\frac{1}{1\cdot01}$	2,716[f]	$\frac{1}{144\cdot30}$	$\frac{1}{\cdot26}$	12,796	12·77	32,410	7-in. of 90 cwt.	
7-in. of 6½ to	0	18,500	$\frac{1}{1\cdot27}$	3,500[f]	$\frac{1}{203\cdot40}$	$\frac{1}{\cdot24}$	18,060	12·21	42,400	7-in. of 6½ tons.	
7-in. of 7 tons	0	16,570	$\frac{1}{1\cdot05}$	3,052	$\frac{1}{208\cdot80}$	$\frac{1}{\cdot19}$	18,732	12·06	42,270	7-in. of 7 tons.	
8-in. of 9 ton	0	16,440	$\frac{1}{\cdot81}$	4,788	$\frac{1}{172\cdot50}$	$\frac{1}{\cdot23}$	24,948	12·13	57,060	8-in. of 9 tons.	
9-in. of 12 to	0	17,280	$\frac{1}{\cdot64}$	4,732	$\frac{1}{232\cdot30}$	$\frac{1}{\cdot17}$	31,612	13·41	88,200	9-in. of 12 tons.	
10-in. of 18 t	0	17,250	$\frac{1}{\cdot42}$	7,504	$\frac{1}{180\cdot50}$	$\frac{1}{\cdot18}$	47,824	13·38	132,700	10-in. of 18 tons.	
11-in. of 25 t	0	17,530	$\frac{1}{\cdot31}$	7,504	$\frac{1}{222\cdot00}$	$\frac{1}{\cdot13}$	63,504	12·78	161,300	11-in. of 25 tons.	
12-in. of 25 t	0	15,520	$\frac{1}{\cdot27}$	7,504	$\frac{1}{233\cdot38}$	$\frac{1}{\cdot13}$	63,504	14·03	194,100	12-in. of 25 tons.	
12-in. of 35 t	0	16,730	$\frac{1}{\cdot21}$	13,328	$\frac{1}{141\cdot90}$	$\frac{1}{\cdot17}$	91,728	11·46	186,900	12-in. of 35 tons.	
12·5-in. of 38	0	17,040	$\frac{1}{\cdot20}$	13,328	$\frac{1}{157\cdot00}$	$\frac{1}{\cdot15}$	98,448	13·45	276,400	12·5-in. of 38 tons.	
16-in. of 80 t	0	19,540	$\frac{1}{\cdot11}$	96,544[g]	$\frac{1}{40\cdot68}$	$\frac{1}{\cdot53}$	275,744	11·33	550,300	16-in. of 80 tons.[a]	
10-in. howr.	0	9,046	$\frac{1}{\cdot67}$	7,140	$\frac{1}{99\cdot49}$	$\frac{1}{\cdot53}$	20,580	14·09	63,270	10-in. howr. of 6 tons.[a]	

[f] S.S. iron. [g] Travelling. [j] Packed.

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COMPARISON OF M.L.R. GUNS,

BY

MAJOR W. KEMMIS, R.A.

	Nature.	Cartridge. Weight, $= w'$.	Length, $= l'$.	Diamr., $= d'$.	Projectile. Weight, $= w$.	Length, $= l$.	Diamr. $= d$.	$w \mid d^2$	Muzzle velocity, $= v$.	Work done upon, $E = \frac{w \cdot v^2}{2g}$	Work done upon per lb. of charge.	Projectile and Cartridge. $w' \mid w$	Work done upon, $= \frac{(w'+w)v^2}{2g}$	Gun. Weight, $= W$.	Length of bore, $= L$.	Diamr. of bore, $= D$.	$\frac{L}{D}$	Average pressure in bore, $= P$.	Average pressure per sq. in., $= p$.	$\frac{W}{p}$	Carriage. Weight, $= W'$	$\frac{W'}{P}$	$\frac{W}{W'}$	Gun and Carriage. Weight, $= W''$.	Velocity of recoil, $= V''$.	Work done upon. $= \frac{W'' \cdot V''^2}{2g}$	Nature.	
		lbs.	ins.	ins.	lbs.	ins.	ins.		ft. secs.	ft. lbs.	ft. lbs.		ft. lbs.	lbs.	ins.	ins.		lbs.	lbs.		lbs.			lbs.	ft. secs.	ft. lbs.		
FIELD.	7-pr. of 200 lbs. (steel).	·75	6·00	2·50	7·38	6·75	2·94	1·17	968	107,400	143,200	$\frac{1}{9 \cdot 84}$	118,300	200	36·00	3·00	12·00	47,320	6,697	$\frac{1}{33 \cdot 48}$	350	$\frac{1}{135 \cdot 20}$	$\frac{1}{1 \cdot 75}$	550	14·31	1,749	7-pr. of 200 lbs. (steel).	FIELD.
	9-pr. of 6 cwt.	1·75	9·25	2·60	9·06	7·93	2·94	·95	1390	271,700	155,300	$\frac{1}{5 \cdot 17}$	324,300	672	66·00	3·00	22·00	68,580	9,705	$\frac{1}{14 \cdot 44}$	1,280	$\frac{1}{53 \cdot 58}$	$\frac{1}{1 \cdot 90}$	2,049	7·33	1,711	9-pr. of 6 cwt.	
	9-pr. of 8 cwt.	1·75	9·25	2·60	9·06	7·93	2·94	·95	1388	271,100	155,000	$\frac{1}{5 \cdot 17}$	323,500	896	63·50	3·00	21·17	71,580	10,130	$\frac{1}{14 \cdot 23}$	1,280	$\frac{1}{55 \cdot 93}$	$\frac{1}{1 \cdot 42}$	2,273	6·60	1,538	9-pr. of 8 cwt.	
	16-pr. of 12 cwt.	3·00	9·75	3·30	16·19	10·00	3·54	·77	1338	450,100	150,034	$\frac{1}{5 \cdot 39}$	533,400	1,344	68·40	3·60	19·00	109,100	10,730	$\frac{1}{9 \cdot 55}$	1,431	$\frac{1}{78 \cdot 26}$	$\frac{1}{1 \cdot 06}$	2,896	8·86	3,534	16-pr. of 12 cwt.	
	25-pr. of 18 cwt.	4·00	11·00	3·60	25·00	12·85	3·94	·62	1277	633,000	158,250	$\frac{1}{8 \cdot 25}$	734,300	2,016	88·00	4·00	22·00	114,500	9,109	$\frac{1}{4 \cdot 52}$	1,700	$\frac{1}{67 \cdot 33}$	$\frac{1}{\cdot 84}$	3,755	9·86	5,671	25-pr. of 18 cwt.	
	40-pr. of 34 cwt.	7·00	14·00	4·30	38·09	13·53	4·69	·57	1293	988,800	141,257	$\frac{1}{5 \cdot 44}$	1,170,000	3,808	85·50	4·75	18·00	196,400	11,090	$\frac{1}{2 \cdot 91}$	3,460	$\frac{1}{56 \cdot 78}$	$\frac{1}{\cdot 90}$	7,268	8·02	7,263	40-pr. of 34 cwt.	
	40-pr. of 35 cwt.	7·00	14·00	4·30	38·09	13·53	4·69	·57	1300	999,300	142,771	$\frac{1}{5 \cdot 44}$	1,183,000	3,920	104·50	4·75	22·00	156,900	8,857	$\frac{1}{2 \cdot 25}$	3,460	$\frac{1}{45 \cdot 34}$	$\frac{1}{\cdot 88}$	7,380	7·94	7,228	40-pr. of 35 cwt.	
	64-pr. of 64 cwt.	12·00	13·50	6·00	64·00	16·00	6·22	·60	1457	2,110,000	175,833	$\frac{1}{5 \cdot 33}$	2,505,000	7,168	97·50	6·30	15·47	358,000	11,480	$\frac{1}{1 \cdot 60}$	3,715	$\frac{1}{96 \cdot 34}$	$\frac{1}{\cdot 51}$	10,883	10·17	17,500	64-pr. of 64 cwt.	
	6·3-in. howr. of 18 cwt.[a]	4·00	8·00	6·00	64·00	16·00	6·22	·60	784	610,800	152,700	$\frac{1}{16 \cdot 00}$	648,900	2,016	45·00	6·30	7·14	210,400	6,751	$\frac{1}{1 \cdot 35}$	3,480	$\frac{1}{60 \cdot 46}$	$\frac{1}{1 \cdot 72}$	5,496	9·70	8,028	6·3-in. howr. of 18 cwt.[a]	
	8·0-in. howr. of 46 cwt.	10·00	9·00	6·80	180·68	24·17	7·92	·35	790	1,750,000	175,000	$\frac{1}{18 \cdot 06}$	1,848,000	5,152	48·00	8·00	6·00	568,400	11,320	$\frac{1}{2 \cdot 19}$	4,802	$\frac{1}{118 \cdot 40}$	$\frac{1}{\cdot 93}$	9,954	15·13	35,390	8·0-in. howr. of 46 cwt.	
GARRISON AND NAVAL.	64-pr. of 58 cwt.	8·00	9·45	6·00	64·00	16·00	6·22	·60	1245	1,540,000	192,500	$\frac{1}{8 \cdot 00}$	1,732,000	6,496	108·45	6·29	17·24	209,900	6,757	$\frac{1}{1 \cdot 04}$	1,232[d]	$\frac{1}{170 \cdot 40}$	$\frac{1}{\cdot 19}$	7,728	11·60	16,140	64-pr. of 58 cwt.	GARRISON AND NAVAL.
	64-pr. of 71 cwt.	8·00	9·45	6·00	64·00	16·00	6·22	·60	1230	1,503,000	187,875	$\frac{1}{8 \cdot 00}$	1,691,000	7,952	103·27	6·29	16·41	215,800	6,947	$\frac{1}{\cdot 87}$	1,596[e]	$\frac{1}{135 \cdot 20}$	$\frac{1}{\cdot 20}$	9,548	9·27	12,760	64-pr. of 71 cwt.	
	64-pr. of 64 cwt.	10·00	11·50	6·00	64·00	16·00	6·22	·60	1383	1,906,000	190,600	$\frac{1}{6 \cdot 40}$	2,199,000	7,168	97·50	6·30	15·47	306,800	9,942	$\frac{1}{1 \cdot 37}$	1,326[f]	$\frac{1}{231 \cdot 40}$	$\frac{1}{\cdot 18}$	8,494	12·05	19,150	64-pr. of 64 cwt.	
	80-pr. of 5 tons	10·00	11·50	6·00	79·88	19·00	6·22	·48	1240	1,905,000	190,500	$\frac{1}{7 \cdot 98}$	2,146,000	11,200	113·25	6·29	18·00	253,000	8,145	$\frac{1}{\cdot 72}$	1,568[d]	$\frac{1}{161 \cdot 40}$	$\frac{1}{\cdot 14}$	12,768	8·73	15,110	80-pr. of 5 tons.	
	7-in. of 90 cwt.	14·00	13·90	6·40	116·75	20·40	6·92	·41	1250	2,832,000	202,300	$\frac{1}{7 \cdot 34}$	3,172,000	10,080	111·00	7·00	15·85	392,000	10,190	$\frac{1}{1 \cdot 01}$	2,716[f]	$\frac{1}{144 \cdot 30}$	$\frac{1}{\cdot 28}$	12,796	12·77	32,410	7-in. of 90 cwt.	
	7-in. of 6½ tons	30·00[b]	23·00	6·50	114·63[c]	16·50	6·92	·41	1525	4,138,000	137,933	$\frac{1}{3 \cdot 82}$	5,222,000	14,560	111·00	7·00	15·85	712,000	18,500	$\frac{1}{1 \cdot 27}$	3,500[f]	$\frac{1}{203 \cdot 40}$	$\frac{1}{\cdot 24}$	18,060	12·21	42,400	7-in. of 6½ tons.	
	7-in. of 7 tons	30·00[b]	23·00	6·50	114·63[c]	16·50	6·92	·41	1561	4,337,000	144,567	$\frac{1}{3 \cdot 82}$	5,473,000	15,680	126·00	7·00	18·00	637,500	16,570	$\frac{1}{1 \cdot 05}$	3,052	$\frac{1}{208 \cdot 80}$	$\frac{1}{\cdot 19}$	18,732	12·06	42,270	7-in. of 7 tons.	
	8-in. of 9 tons	35·00[b]	21·50	7·50	179·31[c]	19·25	7·92	·35	1413	5,558,000	158,800	$\frac{1}{5 \cdot 12}$	6,642,000	20,160	118·00	8·00	14·75	823,900	16,440	$\frac{1}{\cdot 81}$	4,788	$\frac{1}{172 \cdot 50}$	$\frac{1}{\cdot 23}$	24,948	12·13	57,060	8-in. of 9 tons.	
	9-in. of 12 tons	50·00[b]	23·00	8·50	248·44[c]	21·45	8·92	·32	1420	7,780,000	155,600	$\frac{1}{4 \cdot 97}$	9,344,000	26,880	125·00	9·00	13·89	1,099,000	17,280	$\frac{1}{\cdot 64}$	4,732	$\frac{1}{232 \cdot 30}$	$\frac{1}{\cdot 17}$	31,612	13·41	88,200	9-in. of 12 tons.	
	10-in. of 18 tons	70·00[b]	25·50	9·50	398·88[c]	26·30	9·92	·24	1364	11,530,000	164,428	$\frac{1}{5 \cdot 69}$	13,540,000	40,320	145·50	10·00	14·55	1,354,000	17,250	$\frac{1}{\cdot 42}$	7,504	$\frac{1}{180 \cdot 50}$	$\frac{1}{\cdot 18}$	47,824	13·38	132,700	10-in. of 18 tons.	
	11-in. of 25 tons	85·00[b]	25·50	10·50	532·75[c]	28·30	10·92	·22	1315	14,300,000	168,212	$\frac{1}{6 \cdot 20}$	16,590,000	56,000	145·00	11·00	13·18	1,665,000	17,530	$\frac{1}{\cdot 31}$	7,504	$\frac{1}{222 \cdot 00}$	$\frac{1}{\cdot 13}$	63,504	12·78	161,300	11-in. of 25 tons.	
	12-in. of 25 tons	85·00[b]	22·00	11·50	600·44[c]	29·20	11·92	·23	1300	15,750,000	185,294	$\frac{1}{7 \cdot 06}$	17,990,000	56,000	145·00	12·00	12·08	1,755,000	15,520	$\frac{1}{\cdot 27}$	7,504	$\frac{1}{233 \cdot 38}$	$\frac{1}{\cdot 13}$	63,504	14·03	194,100	12-in. of 25 tons.	
	12-in. of 35 tons	110·00[b]	28·00	11·50	698·31[c]	31·30	11·92	·20	1300	18,320,000	166,545	$\frac{1}{8 \cdot 34}$	21,200,000	78,400	162·50	12·00	13·54	1,892,000	16,730	$\frac{1}{\cdot 21}$	13,328	$\frac{1}{141 \cdot 90}$	$\frac{1}{\cdot 17}$	91,728	11·46	186,900	12-in. of 35 tons.	
	12·5-in. of 38 tons	130·00[b]	30·50	12·00	802·25[c]	33·00	12·42	·19	1420	25,120,000	193,232	$\frac{1}{6 \cdot 17}$	29,180,000	85,120	198·00	12·50	15·84	2,091,000	17,040	$\frac{1}{\cdot 20}$	13,328	$\frac{1}{157 \cdot 00}$	$\frac{1}{\cdot 15}$	98,448	13·45	276,400	12·5-in. of 38 tons.	
	16-in. of 80 tons[a]	370·00	64·00	14·75	1700·00	43·40	15·87	·14	1510	60,190,000	162,675	$\frac{1}{4 \cdot 59}$	73,300,000	179,200	288·00	16·00	18·00	3,927,000	19,540	$\frac{1}{\cdot 11}$	96,544[g]	$\frac{1}{40 \cdot 05}$	$\frac{1}{\cdot 53}$	275,744	11·33	550,300	16-in. of 80 tons.[a]	
	10-in. howr. of 6 tons[a]	10·00	6·00	8·25	398·25	30·55	9·92	·24	710	3,118,000	311,800	$\frac{1}{39 \cdot 82}$	3,197,000	13,440	60·00	10·00	6·00	710,400	9,046	$\frac{1}{\cdot 87}$	7,140	$\frac{1}{99 \cdot 49}$	$\frac{1}{\cdot 53}$	20,580	14·09	63,270	10-in. howr. of 6 tons.[a]	

[a] Experimental. [b] Battering charge, pebble. [c] Palliser shell. [d] L.S. wood. [e] S.S. wood. [f] S.S. iron. [g] Travelling. [j] Packed.

[h] It is assumed that the same velocity is communicated to the cartridge as to the projectile, it being impossible for several reasons to know what that velocity actually is.

[i] This is calculated, on the supposition that it is uniform for the length of its action, from the work done upon the charge.

If $\frac{C}{n}$ in equation (3) be assumed constant (which is very nearly the case when similar guns are fired with charges of powder having the same proportion to the weights of the projectiles), then

$$\text{energy of recoil} \propto \frac{wv^2}{2g} \times \frac{w}{W''},$$

or

$$\text{energy of recoil} \propto \text{muzzle energy of projectile} \times \frac{w}{W''};$$

so that if the muzzle energy of projectile is constant, the energy of recoil varies *directly* as the weight of the projectile and *inversely* as the weight of the gun and carriage. The object of the artillerist is clearly to make the muzzle energy of the projectile a maximum, and to reduce the energy of recoil as much as possible consistent with the requirements of the particular gun for *range* and *mobility*.

How the energy of recoil may be reduced.

The energy of recoil may be reduced either (1) by decreasing the weight of the projectile, (2) by decreasing the muzzle velocity, or (3) by increasing the weight of gun and carriage. But if the *weight of the projectile* be much decreased, the gun will have less range and penetration, although there will be the advantage of carrying more rounds of ammunition in the limber and wagon; if the *muzzle velocity* be much decreased, the trajectory will not be so flat, the accuracy of fire will not be so good (especially with shrapnel shell); if the *weight of the gun* and carriage be much increased, it becomes more difficult to move it from place to place, and consequently its mobility becomes impaired. When the recoil cannot thus be reduced to the required limit, it becomes necessary to resort to mechanical or other means for checking it.

The ratio of the weight of projectile to the weight of the gun and carriage is therefore determined by the nature of service for which it is to be employed—whether for *indirect* fire with low velocities, or for *direct* fire with high velocities—as well as the mobility required for the particular service.

Kemmis's table of service M.L.R. ordnance.

Major Kemmis's Table of Comparison of M.L.R. Guns gives the weight, length, and diameter of the cartridges and projectiles used with them; the ratio of the weights of their projectiles and charges; the work done on projectile and cartridge; the weight of gun and carriage; the velocity of recoil; the work done in recoil upon, or energy of recoil of, gun and carriage; and the muzzle velocity corresponding to the charge.

EXAMPLE.—Required, the velocity of recoil of the 9-pr. M.L. gun of 6 cwt.

On referring to the table, weight of 9-pr. shell = 9·06 lbs., weight of charge = 1·75 lbs., muzzle velocity = 1390 f.s., weight of gun and carriage packed = 2049 lbs. Then from equation (1)

$$V'' = \text{velocity of recoil} = \frac{(w + Cw')v}{W''};$$

or taking $C = 1$, for purposes of comparison,

$$V'' = \frac{(w + w')v}{W''} = \frac{(9{\cdot}06 + 1{\cdot}75)\ 1390}{2049} = 7{\cdot}33 \text{ f.s.},$$

as in the table. Also,

$$\text{energy of recoil (or work done in recoil)} = \frac{W''V''^2}{2g} = \frac{2049 \times (7{\cdot}33)^2}{2 \times 32{\cdot}2} = 1711 \text{ ft. lbs.}$$

For destructive effect on the carriage caused by the shock of discharge of the gun, see "Treatise on Military Carriages," pp. 30–33.

CHAPTER III.

Explosion and Pressure in the Bore of a Gun.

Explosion of Gunpowder.—Explosion of Gun-cotton.—Comparison of the Results of Explosion of R.L.G. and P. Powder.—Objects sought after by the use of Powder as a Propelling Agent.—Causes which affect the Time of Explosion of Powder.—Different Powders required to give the best Results in Light and Heavy Guns.—Effect of Explosion in the Bore of a Gun.—Experiments with the Noble Chronoscope.—Crusher Gauge.—Manner of Explosion of Powder in a Gun.—Resistance to the Motion of a Projectile in the Bore of a Gun.—Resistance to the Motion of Translation.—Resistance to the Motion of Rotation.—Resistance due to Friction.—The Maximum Limit of Pressure allowable in the Bore of Heavy Guns.

Explosion of gunpowder.

The principal advantage of gunpowder, over gun-cotton and other explosive substances for use with ordnance, is its comparatively slow explosion.

The progressive nature of the explosion of gunpowder allows of a certain interval of time to elapse before the maximum pressure of the gas is exerted in the bore of the gun. The projectile then has time to move, and consequently begins to move while the powder is exploding; so that an increasing space is provided for the rapidly expanding gas, which changes the character of the force exerted by the gas more into the nature of a pressure than an impulse.

An impulse is theoretically an indefinitely large force acting absolutely *instantaneously;* and although, strictly speaking, there are no forces in nature which answer to the above definition, yet there is a close approximation to it in the detonation of gun-cotton and other explosive substances.

Explosion of gun-cotton.

It is this approximation of the force of exploded gun-cotton to that of an impulse which renders it (in its present state) unfit for general use in the service of ordnance, straining as it does inordinately both projectile and gun.

Comparison of the results of explosion of R. L. G. and P. powder.

In quick-burning powders, such as R.L.G., a shorter interval of time elapses before the maximum pressure of the charge is exerted than in slow-burning powders like P. powder.

The *time of explosion* has an important effect on the maximum pressure in the powder-chamber. As the time of explosion increases, this pressure diminishes, and *vice versâ*.

From recent experiments with P. and R.L.G. powders in the bore of a 10-in. rifled M.L. gun of 18 tons, it was calculated that the time elapsed, before the maximum pressure was exerted in the bore, was with the (slow-burning) pebble powder ·00437 sec., and with the (quick-burning) R.L.G. powder ·00070 sec.* The maximum pressure of the P. powder was about 18 tons on the square inch, being considerably less than that exerted (22 tons) by the R.L.G. powder. (*Vide* Plate I.)

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* *Vide* "Researches on Fired Gunpowder," by Capt. A. Noble, F.R.S., and Professor Abel, F.R.S., p. 118.

Table showing the Results of Explosion of P. and R.L.G. Powder.

Charge of powder.	Weight of projectile.	Muzzle velocity.	Maximum pressure in the chamber.	Time of max. press.	Distance traversed in that time by projectile.
	lbs.	f.s.	tons per sq.in.	sec.	ins.
70 lbs. P.	300	1527	18	·00437	6·0
60 lbs. R.L.G.	300	1480	22	·00070	·6

The force developed, then, by fired R.L.G. powder approximates more to the nature of an impulse than that developed by fired P. powder, and consequently exerts a more destructive strain on both gun and projectile. It is for this reason that P. powder has been substituted for R.L.G. powder in the charges of the heavy rifled M.L. guns.

Objects sought after by the use of powder as a propelling agent.

The chief object to be attained by the use of powder as an explosive agent in the bore of a gun is to transmit the greatest amount of *muzzle energy* to the projectile with the least possible strain to the gun—*i.e.*, to transmit the maximum of *total pressure* to the base of the projectile, throughout the bore of the gun, with the minimum of *local pressure* to the powder-chamber.

Causes which affect the time of explosion of powder.

The *time of explosion* of powder depends principally on the size and shape of the grains, their density and hardness, the amount of glazing given to them, and the quantity of moisture contained in the powder.

Suppose a powder similar in all respects except in the size and shape of the grains; then the time of explosion, or conversion of the powder into gas, depends on the *rate of ignition* of the grains, and the *time of combustion* of each grain.

The rate of ignition of the grains depends on the facility with which the flame can penetrate to contiguous grains—*i.e.*, on the magnitude of the interstices between the grains, depending principally on the shape of the grains; while the time of combustion depends on the bulk or size of the grains themselves—*i.e.*, the smaller the *size* the quicker the combustion. These conditions (more fully explained in a treatise on gunpowder),* are to a certain extent opposed to one another; so that it will readily be understood that there is some shape and size of grain which would render the explosion the quickest possible.

A charge made up of large-grain powder explodes more slowly than that made up of a small-grain powder; for although, on account of the larger interstices between the grains of the former, ignition is more rapid, yet the combustion of each grain is slower than in the latter case. The former is called a slow-burning powder (comparatively), the latter a quick-burning powder. It follows, then, that in order to secure uniform results with similar charges of powder, the size and shape of the grains must be as nearly as possible the same.

The time of explosion is also affected by the density of the powder.

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* *Vide* "Short Notes on Gunpowder, and its Manufacture," by Major Wardell, R.A.

The denser the grain the more powder there is in it for a given size, and consequently the time of combustion is longer. Other things being equal, the denser the powder the slower burning it is, and the less the pressure in the bore of the gun.

The amount of moisture in the powder has the effect of modifying its time of explosion. The accompanying table shows the effect of moisture in powder: as the per-centage of moisture increases, the time of explosion is lengthened, and the pressure in the gun and the muzzle velocity of the projectile decreased.

Table showing the Effect of Moisture in Powder on Muzzle Velocity and Pressure in the Gun.

Sample of powder.	Per-centage of moisture.	Muzzle velocity in ft. secs.	Maximum pressure in the bore (ft. tons).
Pebble, $\frac{5}{8}$ in....	·8	1537	21·38
	1·0	1524	20·18
	1·2	1512	19·12
	1·4	1502	18·18

The glazing and hardness of the grains retard the ignition of the powder, and consequently increase the time of explosion.

The time of explosion of powder in a *gun* is further affected by the form of cartridge, diameter of the powder-chamber, amount of air-space, and the point of ignition of the cartridge. (*Vide* Chapter IV.)

With large charges for heavy guns, it becomes especially important, in order to keep down the pressure within limits of safety, to increase the density and size of grain. The time of explosion is thus increased, and for a given charge both the muzzle velocity of projectile and the maximum pressure in the bore are decreased.

Table showing Density and Size of Grain of Powders used with Rifled Ordnance.

Description of powder.	Size of grain.	Mean density.
R.L.G.	4 to 8 meshes to an inch.	1·68
Pebble (P.)	$\frac{5}{8}$-in. cubes.	1·80
Cubical (P.^{2})	$1\frac{1}{2}$-in. cubes.	1·78

Cubical powder (P.^{2}) was introduced for employment in the very large charges used with the 38 and 80-ton guns; since with ordinary pebble (P.) powder, owing to the effect of the *heat* and *pressure* developed in the partial explosion of such large charges, the time of explosion would be diminished, and the local pressure in the powder-chamber would exceed safe limits.

Different powders required to give the best results in light and heavy guns.

In different natures of ordnance, where the charge and calibre vary considerably, great attention must be paid to the regulation of the size and density of the grains of the powder employed, in order to transmit the maximum of muzzle energy to the projectile with the minimum of local pressure on the gun. A light projectile moves easily, and a quick-burning powder is found most suitable; a heavy projectile moves less easily, and a slow-burning powder is found most suitable.

Effect of explosion in the bore of a gun.

When a charge of powder is exploded in a gun, a large quantity of gas is generated, which rapidly expands, and exerts an enormous pressure both on the chamber of the gun and on the base of the projectile. This pressure is usually measured in foot tons on the square inch. (*Vide* p. 38.)

The pressure on the base of the projectile continually varies while it is in the bore of the gun (*vide* Pressure Curves, Plate I.), reaching a maximum a short time after the projectile has moved; then it gradually decreases towards the muzzle. The effect of this pressure on the base of the projectile is to give *velocity* to the projectile, which continually increases towards the muzzle, where it is the greatest, and it is then called the muzzle velocity.

There is a corresponding pressure on the chamber and bore of the gun; as at any given instant of explosion the pressure of the expanding gases may be supposed equal in every direction—*i.e.*, on the base of the projectile and on the walls of the bore. The pressure of fired gunpowder in the bores of guns has been very fully investigated by the Committee on Explosives, under the presidency of Colonel Younghusband, R.A., F.R.S.; and details of experiments are given in the Progress Reports published from time to time by that Committee. By means of the Noble chronoscope and the crusher gauge (for details of which *vide* App. I.), the pressures in a gun at any part of the bore, and the corresponding velocities of the projectile in the bore, can be ascertained.

Experiments with the Noble chronoscope.

The Noble chronoscope measures the time occupied by the projectile in passing over certain known intervals in the bore of the gun. The velocity of the projectile at any part of the bore is thus determined, and thence the pressures necessary to produce such velocities are calculated.

The results are plotted off on a diagram to scale. (*Vide* Plate I.)* The horizontal distances at the bottom of the plate represent the space in feet traversed from the seat of the projectile to the muzzle of the gun. The left-hand vertical column represents a scale of pressure in tons per square inch, or corresponding pressure in atmospheres; the right-hand vertical column represents a scale of velocity in feet per second.

Plate I. shows the result of an experiment made with pebble and R.L.G. powder to determine the pressure and velocity given by them respectively in the bore of a 10-in. M.L. gun, when firing a 300-lb.

* *Vide* "Researches on Fired Gunpowder," Plate XIX.

projectile with battering charges—*i.e.*, with 70 lbs. P., or 60 lbs. R.L.G.*

The continued curves show the results with P. powder, and the dotted curves those with R.L.G. powder. From this diagram the pressure and velocity may be seen by inspection at any part of the bore of the gun. By comparing the pressure curves, the advantage of P. over R.L.G. powder is well shown. The maximum pressure in the gun in each case is represented by the vertex of the curve, and the work done on the projectile is represented by the respective areas enclosed by the curves. The area of the P. pressure curve is greater than that of the R.L.G. pressure curve, while the vertex is lower; which indicates that the muzzle energy of the projectile is greater, and that the maximum pressure in the gun is less, when the P. powder charge is fired instead of the charge of R.L.G. powder.

Crusher gauge.

Another method of determining the pressure in the bore of a gun is by means of the crusher gauge. (*Vide* App. I.) This is done by direct measurement, and is a rougher method of approximating to the true pressure than that by the chronoscope. However, the pressures calculated from chronoscopic experiments and those observed directly by means of the crusher gauge agree very closely, when slow-burning pebble powder is used; but when a quick-burning powder like R.L.G. is used, the agreement is not so close, owing to the intense local action which is set up in the combustion of such powders, which produces anomalous local pressure in the chamber of the gun.†

Generally speaking, then, the chronoscope measures the *mean pressure* and the crusher gauge the *local pressure* in the powder-chamber; and by the combined use of both these methods of experimenting, practical results of the highest utility have been arrived at.

Manner of explosion of powder in a gun.

When a gun is fired, the charge of powder is very rapidly exploded, and *practically* (so far as useful effect is obtained from its combustion) explosion may be supposed to be completed when the *maximum pressure* is obtained. Some portion of the charge, no doubt, is ignited during the after passage of the projectile to the muzzle, and is blown out of the gun only partially exploded, more especially when battering charges of P. powder are fired; but the useful effect of this after combustion is only a small per-centage of the whole. It must not be supposed that the powder does comparatively little work after the maximum pressure has been attained: it is quite the contrary; but only that, practically, explosion is completed in a very short space of time. An inspection of the diagram (Plate I.) shows the general conditions of explosion very clearly. The maximum pressure in the powder-chamber was in this instance attained with R.L.G. powder when the projectile had moved $\frac{6}{10}^{\text{ths}}$ of an inch; with P. powder when the projectile had moved 6 ins. The powder, then, is not *instantaneously* exploded; but supposing the explosion to be practically completed when the maximum pressure is reached, it will be seen by

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* *Vide* Table showing Results of Explosion, &c., of P. and R.L.G. (p. 48).

† For information on this point, *vide* a paper by Major Morgan, R.A., late Assistant Superintendent Royal Gunpowder Factory, Waltham Abbey, on "The Determination of the Explosive Force of Gunpowder." ("Proceedings, R.A. Institution," Vol. VII. p 430.)

reference to the Table showing Results of Explosion, &c. (p. 48), that the explosion of 60 lbs. R.L.G. powder takes place in about $\frac{1}{6}^{\text{th}}$ of the time taken to explode 70 lbs. of P. powder under similar conditions.

It will be seen from the diagram (Plate I.) that the pressure due to explosion increases very rapidly to a maximum, then at first it rapidly, and afterwards more gradually, decreases towards the muzzle; owing to the continually increasing space for expansion of the gas, caused by the continually increasing forward velocity of the projectile.

Resistance to the motion of a projectile in the bore of a gun.

The effect of the pressure in the bore is to overcome the resistance to motion of the projectile, and to communicate velocity to the projectile. The resistances to the motion of a projectile in the bore of a gun must then be considered.

They may be classified thus :—

(1) The resistance to the motion of *translation* of the projectile.
(2) The resistance to the motion of *rotation* of the projectile.
(3) The *frictional* resistances of the studs and gas-check, opposing the motions of translation and rotation.

Resistance to the motion of translation.

The resistance to the motion of translation of the projectile depends on its weight and the rate of increase of its velocity conjointly. Thus

$$R \propto Wf;$$

where R denotes resistance, W weight of projectile, f the acceleration of the projectile* (or the rapidity with which velocity is communicated to it). The acceleration depends on the rapidity of explosion; and consequently the resistance to motion for the same weight of projectile would be greater in the case of a quick-burning than with a slow-burning powder. This would intensify the pressure in the powder-chamber, as has been shown.

A small difference in the weight of the projectiles, when a slow-burning powder is used, only increases slightly the maximum pressure in the bore. In experiments with a 12-in. gun of 38-tons, the Committee on Explosives found that the effect of increasing the weight of the shot from 700 lbs. to 800 lbs., while firing the same charge of P. powder, did not appear sensibly to increase the maximum pressure in the bore.† Hence it becomes possible to fire very heavy projectiles without increasing inordinately the pressure in the gun, by the employment of very slow-burning powder.

Resistance to the motion of rotation.

The resistance to the motion of rotation of the projectile is only a small per-centage of the resistance to the motion of translation. (*Vide* p. 40). This subject has been very fully discussed in the pages of "Proceedings, R.A. Institution" (Vol. VIII. p. 359), by Captain A. Noble, F.R.S., in a paper "On the Pressure required to give Rotation to Rifled Projectiles." Captain Noble states that in the 10-in. gun

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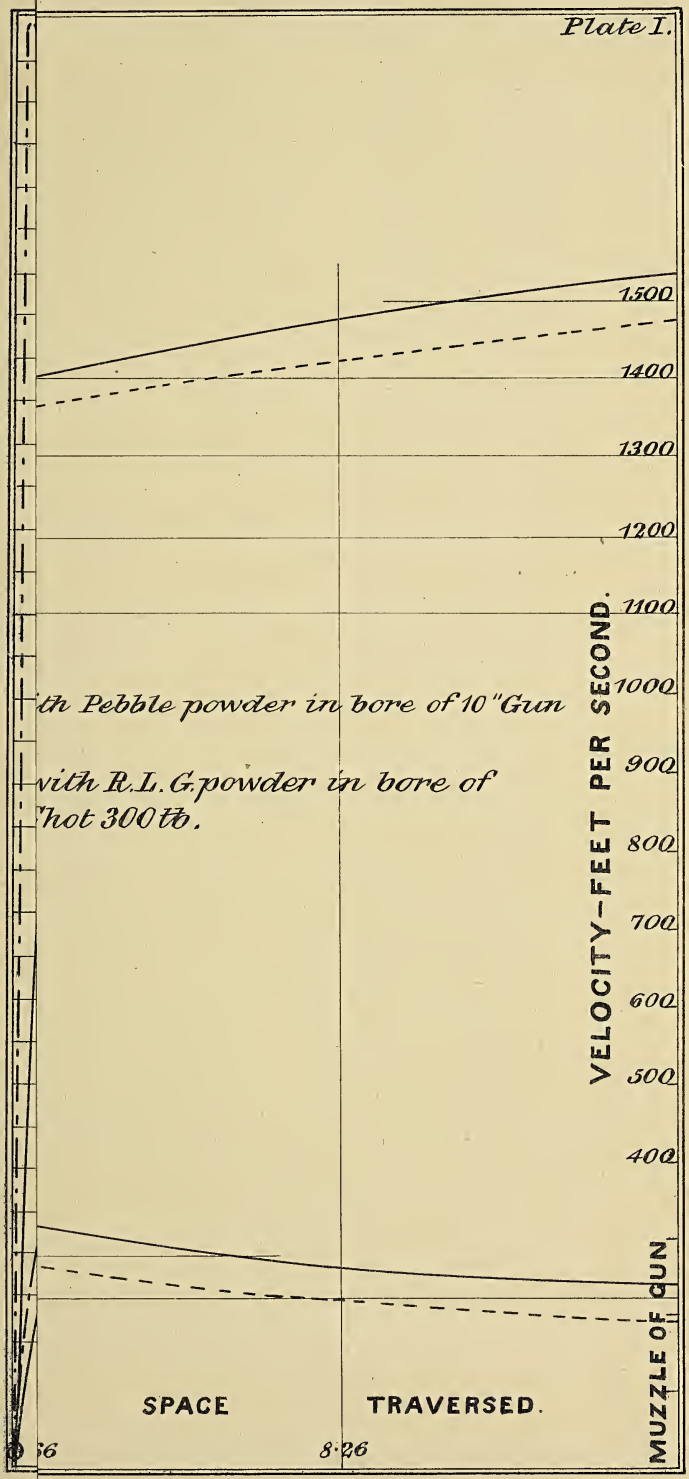
* The acceleration of the projectile in the bore (or the rate of increase of its velocity in a given time) is variable, owing to the variable pressure of the powder gas, and the varying resistances which are opposed to the motion of the projectile.

† *Vide* "Report on the Experimental Rifled M.L. Gun of 38 tons."

AND R.L.G POWDERS.



PRESSURE AND VELOCITY CURVES WITH PEBBLE AND R.L.G POWDERS.

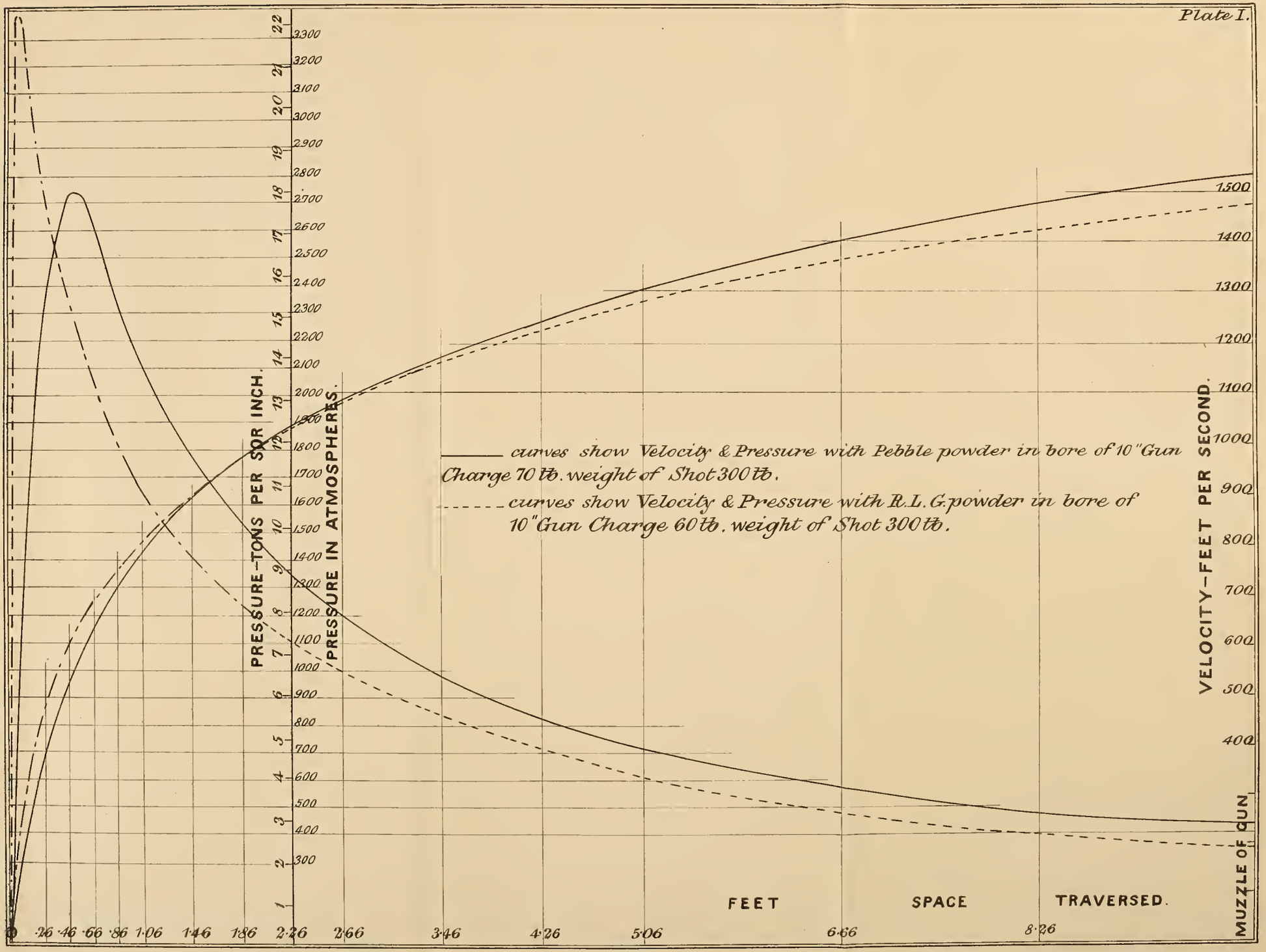


Plate I.
PRESSURE-TONS PER SQR INCH.
PRESSURE IN ATMOSPHERES.
VELOCITY-FEET PER SECOND.
MUZZLE OF GUN
FEET
SPACE
TRAVERSED.
curves show Velocity & Pressure with Pebble powder in bore of 10"Gun Charge 70 lb. weight of Shot 300 lb.
curves show Velocity & Pressure with R.L.G. powder in bore of 10"Gun Charge 60 lb. weight of Shot 300 lb.
·26 ·46 ·66 ·86 1·06 1·46 1·86 2·26 2·66 3·46 4·26 5·06 6·66 8·26

(and other guns similarly rifled), it is about $2\frac{1}{4}$ per cent. The increase of pressure in the bore tending to burst the gun, due to the resistance to the motion of rotation of the projectile, is very small: no sensible difference of pressure could be detected when the 10-in. gun was fired under similar conditions of charge and projectile, whether rifled or not —*i.e.*, whether rotation was imparted to the projectile or not.

Resistance due to friction.

The resistance due to friction with the B.L. Armstrong guns is considerable—the friction extending over the whole of the surface of the projectile which is in contact with the bore; but in the service M.L. guns it principally arises from the friction between the edge of the studs and the driving surface of the grooves. With the M.L. guns, the projectiles are in most cases approximately centred; so that there is little or no friction between the plane surfaces of the studs and grooves. The coefficient of friction between the edge of the studs and the driving surface of the grooves may be taken to be about ·17.

The maximum limit of pressure allowable in the bore of heavy guns.

In experimenting with powders of different shapes and densities, it has been considered desirable to assign a certain limit to the maximum admissible pressure in the powder-chamber, so as to avoid any undue strain on the material of the inner tube of the gun when repeatedly fired. The extreme limit is 25 tons on the square inch. The battering charges of the heavy Woolwich guns are regulated so as not to exceed this limit. With the 38 and 80-ton guns, it is considered desirable that the limit should not exceed 20 tons on the square inch.

CHAPTER IV.

Work Done by a Charge of Powder in connection with Muzzle Velocity and Pressure in the Bore.

Work done by Powder.—The Velocity of a Projectile at any point in the Bore of a Gun.—Muzzle Velocity.—Approximation to the Muzzle Velocity of a Gun by means of Noble's Tables.—Circumstances affecting Muzzle Velocity.—Charge of Powder.—Nature of Powder.—Weight of Projectile.—Length of Bore.—Calibre.—Diameter of Chamber, and Cubic Space occupied by the Charge.—Windage.—Position of the Vent.—Twist of Rifling.

Work done by powder.

Comparatively little was known of the work done by the explosion of gunpowder until it was made the subject of enquiry by Captain A. Noble, late R.A., F.R.S., and Professor Abel, F.R.S. Their researches have thrown much light on the subject. The results of their experiments are expressed by connecting the number of volumes of expansion of the powder charge in the bore of the gun with the maximum work per pound of powder which the powder is capable of realising.

The amount of work capable of being done on a projectile by the charge of powder in a gun depends principally upon the ratio of the cubic space occupied by the charge to the cubic capacity of the bore of the gun. This is *modified* in practice—

(1) By the nature of the powder—its density, hardness, &c., and the size and shape of its grains.

(2) The method of ignition adopted, and the position of the vent.

(3) The amount of air-space allowed. (*Vide* p. 61.)

(4) The weight of the projectile, its resistance to motion (both of translation and rotation), frictional and other resistances—whether due to compression (as in the Armstrong B.L. system), or to expansion (as in the polygroove M.L. system), or to the gas-checks used with Woolwich guns.

(5) The quantity of heat absorbed by the gun.

The annexed table is taken from the results obtained by Noble and Abel. The curve deduced from their experiments is given in Plate II.

A pound of powder is taken to occupy a space of 27·7 cub. ins.

The number of volumes of expansion of the powder charge in the bore of a gun is obtained by dividing the cubic capacity of the bore of the gun by the cubic space actually occupied by the charge under the above conditions.

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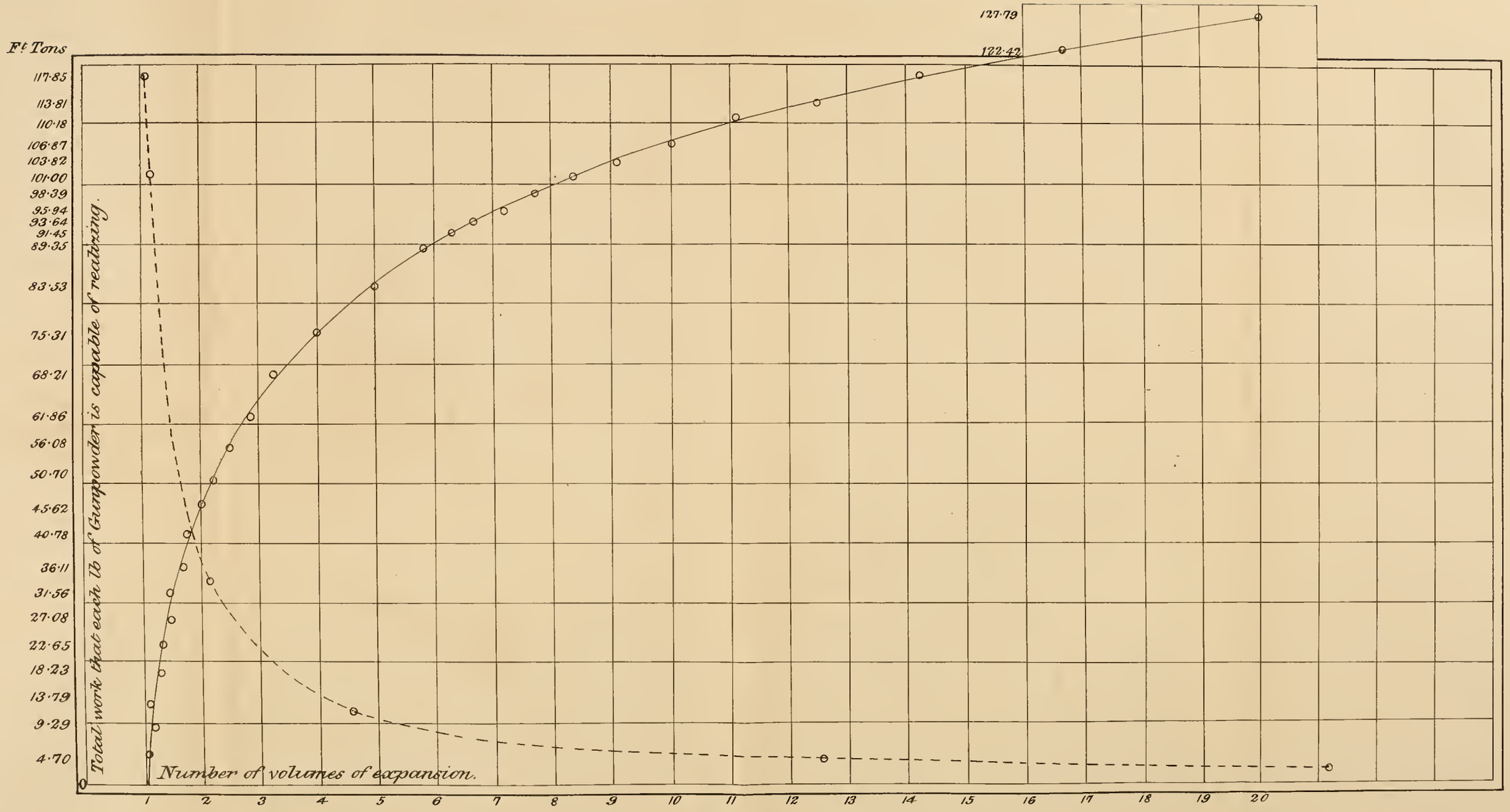
oyal Gun

CAPTN ANDREW NOBLE'S TABLE
OF
WORK EFFECTED BY GUNPOWDER.

Plate II.



1 lb of Powder is taken to occupy a Space of 27·7 Cubic inches.

N.B.—The curves in this Plate were worked out graphically by Captain Owen, R.A., Asst. Supt. Royal Gun Factories, and the Plate is extracted from Plate *E* in the "Treatise on the Construction of Ordnance."

Table showing Work Done per pound of Powder in a Gun.

Number of volumes of expansion in the bore.	Total work the powder is capable of realising per pound burnt, in ft. tons.	diff.	Number of volumes of expansion in the bore.	Total work the powder is capable of realising per pound burnt, in ft. tons.	diff.
5·0	83·53		7·6	97·96	
		72			43
5·1	84·25		7·7	98·39	
		70			42
5·2	84·95		7·8	98·81	
		69			42
5·3	85·64		7·9	99·23	
		67			41
5·4	86·31		8·0	99·64	
		65			40
5·5	86·96		8·1	100·04	
		64			40
5·6	87·60		8·2	100·44	
		62			40
5·7	88·22		8·3	100·84	
		61			39
5·8	88·83		8·4	101·23	
		60			39
5·9	89·43		8·5	101·62	
		59			38
6·0	90·02		8·6	102·00	
		57			38
6·1	90·59		8·7	102·38	
		55			37
6·2	91·14		8·8	102·75	
		55			37
6·3	91·69		8·9	103·12	
		54			36
6·4	92·23		9·0	103·48	
		53			36
6·5	92·76		9·1	103·84	
		52			35
6·6	93·28		9·2	104·19	
		50			35
6·7	93·78		9·3	104·54	
		50			35
6·8	94·28		9·4	104·89	
		49			34
6·9	94·77		9·5	105·23	
		48			34
7·0	95·25		9·6	105·57	
		47			33
7·1	95·72		9·7	105·90	
		46			33
7·2	96·18		9·8	106·23	
		45			32
7·3	96·63		9·9	106·55	
		45			32
7·4	97·08		10·0	106·87	
		44			
7·5	97·52				
		44			

By means of the above table, the maximum work that can possibly be obtained in any gun by a given charge of powder may be calculated.

Example.—What is the maximum work that can possibly be done by 50 lbs. of P. powder in the 9-in. M.L. gun? (The length of the bore is 125 ins.)

$$\text{Volume of bore} = \frac{\pi}{4} \times 81 \times 125 \text{ cub. ins.},$$

$$\text{volume of charge (50 lbs.)} = 50 \times 27{\cdot}7 \text{ cub. ins.};$$

so that the number of the volumes of expansion of the powder charge contained in the bore of the gun are

$$\frac{\pi \times 81 \times 125}{200 \times 27{\cdot}7} = 5{\cdot}74.$$

From the table, then (by proportional parts), it will be seen that the *maximum* work capable of being performed by the charge of 50 lbs. of P. powder in the 9-in. M.L. gun

$$= 50 \times 88{\cdot}46 = 4423 \text{ ft. tons.}$$

But the actual muzzle velocity of the 9-in. gun, with a 250-lb. projectile and 50 lbs. of P. powder, is about 1420 f.s.; so that the muzzle energy communicated to the projectile is

$$\frac{250 \times (1420)^2}{4480 \times 32{\cdot}2} = 3494 \text{ ft. tons.}$$

A comparison of this with the maximum work that could theoretically be effected by the charge, shows that there is a deficiency of 929 ft. tons of energy not realised in practice. This is due to the *modifications* mentioned above. The greater the weight of the projectile, the more rapid the explosion of the powder, and the less the proportionate amount of heat absorbed by the gun, the more nearly will the maximum theoretical effect of the powder be realised. With service conditions, the heavier the gun the less the proportionate amount of heat absorbed. In the 9-in. gun the per-centage of maximum effect actually realised is

$$\frac{349400}{4423} = 79{\cdot}0.$$

This is called the *factor of effect* for this particular gun and charge.

Captain A. Noble has calculated the factor of effect for every gun and charge in the British service. A table of factors of effect is given in p. 354 of the "Treatise on the Construction and Manufacture of Ordnance in the British Service."

The velocity of a projectile at any point in the bore of a gun.

The velocity of a projectile at any point of the bore depends on its weight, and upon the work done on it up to *that point*. By the rule of work, it follows that

$$\frac{Wv^2}{2g} = kC;$$

where W = weight of projectile,
v = velocity at any point of the bore,
k = work done per pound of powder on projectile up to that point,
C = weight of charge in lbs.;

or

$$v = \sqrt{2g\frac{kC}{W}}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

So that if the work done on a projectile at any point of the bore of a gun is known, its velocity at that point may be determined by formula (1); which, expressed in words, means that the velocity of a projectile at any point of the bore of the gun varies *directly* as the square root of the work done upon it up to that point, and *inversely* as the square root of its weight.

Muzzle velocity.

Consequently, if V represent the muzzle velocity of the projectile, and K the work done on it per pound of powder up to the *muzzle*,

$$V = \sqrt{2g\frac{KC}{W}}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Now, if the work done on a projectile (KC) in a gun is constant, *the muzzle velocity of the projectile varies inversely as the square root of its weight;*

or

$$V \propto \sqrt{\frac{1}{W}}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

But the work done on a projectile by a given charge of powder in the same or similar guns is *slightly increased* when the weight of the projectile is increased. For example: in the 10-in. M.L. gun, with a

charge of 60 lbs. R.L.G. powder, the work done by the powder is increased 5 per cent. when the weight of the projectile is doubled; with a charge of 70 lbs. P. powder, the work done by the powder is increased $8\frac{1}{2}$ per cent. when the weight of the projectile is doubled. In a 3-in. M.L. gun, with a charge of 2 lbs. R.L.G. powder, the work done by the powder was increased 14 per cent. when the weight of the projectile was doubled.

It is evident that when the weight of the projectile is increased, it takes a slightly longer time to move through the bore; so that more time is given for the pressure to act, and consequently a greater useful effect is obtained from the charge, and the factor of effect is increased.

Approximately correct muzzle velocities may be calculated on this principle for projectiles differing slightly in weight when fired from similar rifled guns with the same charge. Thus, if the weight (W) and muzzle velocity (V) of a projectile be known with a particular gun, then the muzzle velocity (V') of another projectile of known weight (W') fired from a similar gun with the same charge may be approximately found by the proportion

$$V' : V :: \sqrt{\frac{1}{W'}} : \sqrt{\frac{1}{W}},$$

or

$$V' = V\sqrt{\frac{W}{W'}}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

It will be seen from formula (2) that if K (the work done per pound of powder) were constant,

$$V \propto \sqrt{\frac{C}{W}}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

or the muzzle velocity of a gun would vary directly as the square root of the weight of its charge, and inversely as the square root of the weight of its projectile. But it has been shown that the work done per pound of powder depends on the number of volumes of expansion of the powder charge contained in the bore of the gun; so that this formula is of no practical use for the calculation of muzzle velocity when the weights of charges vary in the same gun, because the smaller charge has more expansions than the larger when fired in the same gun.

Approximation to the muzzle velocity of a gun, by means of Noble's tables.

A more practical way of approximating to the muzzle velocity of a gun, when the weight of charge and projectile are known, is as follows, by means of Noble's table (p. 55) :—

Example.—Find approximately the muzzle velocity of the 38-ton gun of 12·5 ins., when firing an 800-lb. projectile with 110 lbs. of P. powder. (Length of bore 198 ins.)

The number of volumes of expansion of charge

$$= \frac{\pi \times (12{\cdot}5)^2 \times 198}{4 \times 110 \times 27{\cdot}7} = 7{\cdot}97,$$

then by the table (p. 55) the maximum work capable of being performed by the charge is

$$110 \times 99{\cdot}52 = 10947{\cdot}2 \text{ ft. tons.}$$

Allowing a small per-centage for loss of energy, due to the communication of heat, &c., &c., to the gun—which can only be judged by experience—a very close approximation to the muzzle velocity may be obtained. In this case, deduct 5 per cent. from the maximum theoretic work, in order to approximate to the work actually realised, which would then be 10,400 ft. tons. Substituting in formula (2),

$$\text{muzzle velocity} = \sqrt{2 \times 32{\cdot}2 \, \frac{10400 \times 2240}{800}} = 1369 \text{ f.s.};$$

which is very nearly the muzzle velocity determined by experiment.

The per-centage allowed in any case depends on the modifications alluded to in p. 54—viz., nature of the powder, method of ignition adopted, and the weight of the projectile, besides the amount of air-space allowed for the cartridge—which will be considered in due course. (*Vide* p. 61.)

Circumstances affecting muzzle velocity.

Circumstances which affect the muzzle velocities of projectiles fired out of rifled ordnance may be classified thus:—

Charge of powder.	Diameter of chamber.
Nature of powder.	Cubic space occupied by charge.
Weight of projectile.	Windage.
Length of bore.	Position of vent.
Calibre.	Twist of rifling.

Charge of powder.

By the employment of small charges of powder, the muzzle velocity of the projectile may be as low as desirable. The effect of increasing the charge by equal increments, is to increase the muzzle velocity rapidly at first (*vide* table), then less rapidly—depending on the nature of the powder employed and the length and calibre of the gun.

*9-pr. R.M.L. of 8 cwt.**

Charge.	Weight of shot.	M.V.
lbs.	lbs.	f.s.
1·75	9	1344
2·0	"	1356
2·25	"	1432
2·5	"	1457
2·75	"	1453
2·0	12	1196
2·25	"	1257
2·5	"	1287
2·75	"	1284
3·0	"	1259

Length of bore, 63·5 ins.
Calibre ..... 3 "

By a continued increase of the charge, the muzzle velocity continues to increase slowly until a point is reached (seldom or never attained in practice) when the muzzle velocity would be the greatest possible under the circumstances. Any further increase of the charge would then have the effect of diminishing the velocity until the bore was nearly full of powder, when the velocity would be very slight. It is evident that the larger the charge, the longer the cartridge must be; so that after a *certain limit is reached,* the explosion of the charge becomes incomplete, and the consequently reduced pressure acts on the projectile through an increasingly shorter distance.

* Experiments carried on in the Royal Gun Factories, Woolwich, 1873, by Major Maitland, R.A.

Nature of powder.

The nature of powder employed exercises a considerable influence on the muzzle velocity. With guns firing comparatively small charges, the highest velocity is obtained by using a quick-burning powder—such as R.L.G. powder; but with guns firing large charges, the highest velocity (consistent with safety) is obtained by using a slow-burning powder—such as cubical pebble.

Weight of projectile.

It will be seen from what has been stated (p. 56), that, for a given charge, the muzzle velocity of the projectile varies *approximately* inversely as the square root of its weight.

Length of bore.

The internal space for the expansion of the powder charge in a gun of given calibre depends on the length of bore, and increases proportionately with the length of bore. Since the useful effect of the charge of powder depends (*vide* table, p. 55) on the number of expansions of the powder charge in the bore of the gun, it is evident that more work is done, and consequently a greater muzzle velocity communicated to the projectile, by a given charge of powder in a longer than in a shorter bore. Practically, the length of bore is limited by the necessary limitation of the weight of the gun for its particular service, and in field and siege guns by travelling conditions; so that it is not advisable to exceed certain limits.

Lengthening the bore of a gun not only gives a higher muzzle velocity for the same internal strain on the chamber, but permits of the use of a slower-burning powder; causing less strain on the gun and carriage—which latter is a point of great importance, not only with heavy guns, but also in connection with field and siege artillery equipment. The strain on the interior of the gun is communicated through the trunnions and elevating screw to the carriage; so that the less the maximum strain exerted on the gun, the less will be the maximum strain exerted on the carriage. The object, then, to be attained is to exert a low maximum pressure throughout a long bore, in order to give the projectile a high muzzle energy with as little destructive effect as possible on the gun and carriage. The destructive effect on the carriage depends in a great measure on the maximum pressure in the gun, and will be less in proportion as a lower maximum pressure is obtained in the gun. It is not meant that the work done in recoil exerts no destructive effect on the carriage, but that for a given muzzle energy of the projectile this necessarily destructive effect may be very much modified by the employment of a comparatively slower-burning powder and a long bore.*

The Committee on Explosives experimented on the original gun of 12 ins., of 35 tons, by lengthening the bore 3 ft. On firing the same charge of powder, it was found that the additional length of bore "yielded a gain in muzzle velocity of about 60 f.s., or nearly 5 per cent., on that obtained with the shorter gun."†

Calibre.

As the calibre is increased, the powder charge is burnt more profitably—*i.e.*, more useful effect is obtained from the powder, and the muzzle velocity of the projectile is increased. The internal space for the expansion of the powder charge increases as the square of the

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* *Vide* example, p. 44.

† *Vide* "Report on the Experimental Rifled M.L. Gun of 38 tons."

calibre, so that more work is done by the powder in the larger calibre; or, looking at it in another point of view, as the calibre increases so the base of the projectile is enlarged, and thus a greater surface is exposed to the action of the powder, and consequently the projectile is pushed forward with a greater aggregate pressure, and hence a higher muzzle velocity for a given length of bore results.

But there are other considerations which limit the calibre of guns. For when the calibre of the gun is increased,

(1) The total rending force, tending to burst the gun, increases (supposing the internal pressure per square inch the same) as the calibre.

(2) The resistance of the air to the motion of the projectile increases, and with projectiles of similar weight the velocity is lost more rapidly.

The first consideration operates most powerfully in the heaviest guns; the second in field and siege guns for direct fire.

In experiments with the 38-ton gun, the 12·5-in. calibre imparted a higher muzzle velocity to similar projectiles, when fired with equal charges, than the 12-in. calibre—which was one of the reasons why the 12·5-in. calibre was eventually adopted.

With field guns, on the contrary, the result of experiments has been such as to justify a diminution of calibre for the same weight of projectile; since the remaining velocity, at ordinary artillery ranges, has an important practical effect on the precision and decision of fire.

In order to test the effect of the variation of the calibre of a gun, when firing the same weight of projectile with the same charge, both as regards muzzle velocity and remaining velocity, at a given range, experiments have been made with the polygroove M.L. 12-pr. gun to determine the remaining velocity of the projectile at 1040 yds. from the muzzle, by means of Le Boulengé's chronograph, with the following results:—

Table showing the Result of varying the Calibre of Field Guns.

Weight of projectile.	Weight of charge.	Calibre of gun.	Muzzle velocity.	Remaining velocity at 1040 yds.	Loss of velocity.
lbs.	lbs.	ins.	f.s.	f.s.	f.s.
12	3	3·0	1690	1208	482
12	3	3·2	1718	1144	574

This shows that although the muzzle velocity is slightly greater with the larger (3·2-in.) calibre, yet the remaining velocity at 1040 yds. is considerably greater with the smaller (3·0-in.) calibre.

Diameter of chamber, and cubic space occupied by the charge.

In the more recently constructed M.L. guns the diameter of the powder-chamber has been made larger than the diameter of the bore (or the calibre of the gun); partly to obviate the disadvantage above alluded to, of increasing the diameter of the projectile, and partly to obtain a higher muzzle velocity, with more uniform results.

The muzzle velocity, under certain conditions,* is slightly increased by enlarging the powder-chamber; as the cartridge becomes shorter, and more space is allowed for the expansion of the powder charge. The charge is probably exploded more uniformly and rapidly in a chambered gun; but the disadvantages of too rapid an explosion may be modified by the use of a slow-burning powder, and also by allowing sufficient *air space* behind the projectile, by means of which the extreme pressure of the powder gas is relieved at the critical moment. By chambering the gun, a larger charge of powder may be profitably burnt, with this advantage—that a higher muzzle velocity is obtained with the same maximum pressure per square inch in the chamber, than with a smaller charge in an unchambered gun.

Experiments with chambered guns have been carried out in the Royal Gun Factories, Woolwich, 1873, by Major Maitland, R.A. A 10-in. M.L. gun was chambered to a diameter of 12 ins. for a length of 19 ins. It was fired with a charge of 85 lbs. P., which gave a less maximum pressure than the unchambered gun with the service charge (70 lbs. P.), while the muzzle velocity was increased by 75 f.s.†

But when large charges are rammed up tight, it is found that the pressure in the *powder-chamber* increases, as well as the muzzle velocity —the former sometimes to a dangerous extent. The object of the artillerist is to get the *greatest amount of work out of a gun with safety*, quite irrespective of the means employed. To obtain a high muzzle velocity with a low maximum pressure, it is necessary to maintain that pressure as much as possible while the projectile is moving along the bore. This may be done by *increasing* the ordinary charge of powder (when rammed up tight), and *giving air-space*, so as to allow for the expansion of the powder gas at the first instant of explosion; thus tending to keep the maximum pressure in the powder-chamber within safe limits.

Air-space is usually given by lengthening the cartridge, and then ramming home the projectile, so as just to touch it; but the principle of the employment of an air-space depends on the ratio of the bulk of the charge to the number of cubic inches of space in rear of the projectile. It is usually measured by the number of cubic inches occupied by each pound of powder in the charge, when the projectile is in its proper position for firing.

The amount of cubic space thus occupied by the cartridge has a very marked influence on the pressure in the gun and the muzzle velocity of the projectile. The effect of increasing the cubic space for a given charge of powder is to reduce both the muzzle velocity and also the maximum pressure in the powder-chamber; so that a much larger charge of powder may be fired with safety when a certain amount of air-space is allowed. This has led to the employment of much larger charges in the heaviest guns than were originally contemplated; the maximum pressure being still kept within safe limits, while a considerable increase in muzzle velocity has been obtained.

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* With small charges, chambering reduces velocity; with medium charges, slightly increases velocity; with large charges, greatly increases velocity; but in all cases reduces pressure.

† *Vide* "Treatise on the Construction and Manufacture of Ordnance in the British Service."

Some experiments carried out by the Committee on Explosives with the 38-ton gun, with cubical powder, will serve to illustrate these principles:—

Table showing Experiments with 38-ton Gun, allowing air-space.
(Cubical powder, 1·5 ins.)

Number of round.	Charge.	Shot.	Muzzle velocity.	E, Energy.	P, Mean press. in powder-chamb. per sq. in.	$\frac{E}{P}$	Length of cartridge.	Cubic ins. per pound of powder.
	lbs.	lbs.	f.s.	ft. tons.	tons.		ins.	
1	130*	800	1451	11655	24·5	476·9	28·00	24·6
2	130*	800	1391	10734	19·3	556·1	33·22	30·0
3	180*	800	1541	13176	22·4	587·3	45·37	30·0
4	180†	800	1544	13225	20·8	634·0	36·25	30·0

* Gun unchambered. † Gun chambered.

When cubical powder is rammed up hard, each pound of powder occupies about 24·6 cub. ins.: any additional cubic space occupied shows that a certain amount of air-space has been given. The most suitable amount of air-space depends upon the system of rifling adopted, the nature of the powder, the weight of charge and projectile, and must be experimentally determined. With Woolwich guns and cubical pebble, the most suitable amount of air-space has been found to vary, under present conditions, from 30 to 34 cub. ins. per pound of powder.*

The effect of allowing air-space is well shown by comparing rounds (1) and (2) in the above table. In round (1) the charge is rammed up hard; in round (2) air-space is given, allowing 30 cub. ins. for each pound of powder. The result is that both energy and pressure are reduced, but the *ratio* of energy to pressure is increased—which is important.

The column $\frac{E}{P}$ represents the ratio of energy of projectile to the mean pressure per square inch in the powder-chamber; and the greater this ratio is (while the pressure, P, is kept within safe limits), the more effective is the gun.

Round (3) shows how, under similar conditions of cubic space per pound of powder, the charge may be increased, and consequently the energy of the projectile, while the mean pressure in the powder-chamber is kept within safe limits. The cartridge is rather long—which is a disadvantage, as it has been found that there is a danger in firing very long cartridges (even when air-space is given) of setting up *wave action*, which increases the local pressure in the powder-chamber abnormally. It becomes, therefore, of considerable importance, when very large charges are fired, to chamber the gun—*i.e.*, to increase the diameter of the powder-chamber, and so to reduce the length of the cartridge and the pressure in the chamber.

Round (4) shows the advantage of enlarging the chamber. The weight of charge and projectile are the same as in round (3), but the

* It is not improbable, under certain conditions, that the amount of air-space may yet be still more increased.

cartridge is shorter, the energy slightly greater, the pressure in the powder-chamber less, and—what is of the most importance—the ratio of energy to pressure, $\frac{E}{P}$, is the greatest of all the rounds fired.

When the powder-chamber is enlarged, it must be remembered that the strain on the chamber at any point, or the tendency to burst at that point, depends not upon the pressure per square inch at that point only, but upon the *product* of the pressure per square inch at that point into the number of inches in the diameter; or, in other words, if the pressure per square inch in the chamber remains the same when the chamber is enlarged, the rending strain on the chamber increases as the diameter.

Windage.

The disadvantages of windage have already been pointed out, and the steps which have been taken to remedy these defects by the adoption of gas-checks in the heavy guns. (Page 31.)

The escape of gas by windage not only causes erosion of the bore, but also diminishes the mean pressure on the base of the projectile, and consequently reduces its muzzle velocity. With muzzle-loading guns windage is necessary, to allow of facility of loading; but in all these guns the smallest amount of windage is given consistent with ease and rapidity of loading. In service guns there is no difficulty in sealing the windage, by fixing on a gas-check to the base of the projectile, so that it may be loaded easily, and that, on firing, the shock of discharge may expand it, and seal up the windage. This has been successfully accomplished with the heavy guns, resulting in *increased muzzle velocity*, and consequently greater range and accuracy, and greater power of penetration. This method of sealing the windage will also, in all probability, be applied to muzzle-loading field and siege guns of future construction.

The Committee on Explosives state "that the use of copper gas-checks in the 38-ton gun, when firing 130-lb. charges of 1·5-in. cubical powder, and 800-lb. projectiles, gives an increase of muzzle velocity of about 38 ft. secs. over that obtained with a projectile of the same weight with service *windage*, fired with the same charge—a gain equivalent to an increase in the length of the bore of the gun of about three calibres. This increase is evidently due to the sealing of the windage by the gas-check, whereby the pressure in the powder-chamber is increased slightly, while there is also an increased pressure on the base of the shot."*

Experiments with 35 and 38-ton guns.

A comparison of the results obtained with the 35-ton gun of 12-in. calibre and the 38-ton gun of 12·5-in. calibre, illustrates the above principles. The 38-ton gun was 3 ft. longer in the bore than the experimental 35-ton gun; but in all other respects they were identical, except in calibre. The original charge in the 35-ton gun was 110 lbs. P.

The increase in muzzle velocity due to the various points of difference between the experimental 35-ton gun and the present 38-ton gun, is *approximately*† as follows:—

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* *Vide* "Report on the Experimental Rifled M.L. Gun of 38 tons."

† The weight of the projectile was 700 lbs. with the 12-in. calibre, and was increased to 800 lbs. with the 12·5-in. calibre.

		f.s.
(1)	Increase in velocity due to lengthening the bore 3 ft.* ... =	54
(2)	Increase in velocity due to increase in calibre from 12 ins. to 12·5 ins. ..... =	30
(3)	Increase in velocity due to use of gas-check ..... =	38
(4)	Increase in velocity due to adoption of cubical pebble, and increasing charge from 110 lbs. P. to 130 lbs. P^2. ..... =	35
(5)	Increase in velocity due to still greater increase of charge from 130 lbs. to 180 lbs. $P.^2$, made practicable by allowing air-space and chambering ..... =	150

Position of the vent.

The position of the vent, or the point of ignition of the cartridge, makes a difference (especially when R.L.G. powder is employed) in the rate of explosion of the charge, and influences the muzzle velocity of the projectile, and the pressure in the powder-chamber.

All the heavy M.L. guns are vented on the same principle—*i.e.*, the position of the vent (where the cartridge is ignited) is fixed at a distance of $\frac{4}{10}^{ths}$ of the length of the battering charge from the bottom of the bore. This position of the vent was found to develop the greatest muzzle velocity, when firing large charges of R.L.G. powder. It was found with cubical pebble powder that there was no difference in muzzle velocity, whether the cartridge was lighted at the rear or in the service position, but that there was a considerable increase in the chamber pressure near the base of the projectile when lighted at the rear. Arrangements have therefore been made in the 80-ton gun to light the cartridge at the service position (although using an axial vent), in order to keep the chamber pressure as low as possible.

Field and siege guns are *rear* vented—(1) so as to ensure the ignition of the cartridge, when firing reduced charges, (2) so as to expel the *débris* of the cartridge of a preceding round, when firing service charges, in order to avoid an accident in re-loading. But if these guns were vented near the centre of the cartridge, as in the heavy guns, there would be a gain in muzzle velocity. Experiments have been carried on with rear and forward vents, with the 16-pr., 25-pr., and 40-pr. guns.

Table showing the Effect of altering the Position of the Vent on Muzzle Velocity.

Gun.	Charge, R.L.G.	Muzzle velocity with rear vent.	Muzzle velocity with forward vent.	Gain in M.V.
	lbs.	f.s.	f.s.	f.s.
16-pr.	3	1358	1397	39
25-pr.	5	1332	1430	98
40-pr.	8	1326	1470	144

In the Armstrong B.L. guns the point of ignition is in the axis of the piece; so that the cartridge is ignited at one end, and probably takes a longer time to explode than if ignited near the centre.

There are so many elements of variation with regard to the explosion of different charges of different powders fired from different guns, already pointed out, that sometimes apparently contradictory results are obtained; so that it may be concluded that probably the best position of vent in any gun is that one which offers the most convenience and safety in practice; and then, if necessary, the rate of explosion can

* That is, the bore was lengthened from 162 to 198 ins.

be modified by the nature of powder, form of chamber, amount of air-space, &c., found advisable under the circumstances.

There is a small loss of velocity due to the escape of gas through the vent. In the heaviest guns it becomes of importance to close the orifice of the vent, and so to prevent the wear of the bush caused by the action of the escaping gas.*

Twist of rifling.

The muzzle velocity of a projectile is affected, under similar conditions, by the amount of work absorbed in giving it rotation; but the work absorbed in giving rotation is so small† (about ·2 per cent. of the whole with the 16-pr. field gun), that practically there is very little difference in the muzzle velocity from this cause in service guns.

From experiments made with the 8-in. M.L. gun, rifled (1) with increasing twist—0 to 1 in 40 calibres, (2) with uniform twist—1 in 40 calibres, and fired under similar conditions of weight of projectile and charge of powder, it was found that in point of accuracy of fire the increasing twist had the advantage, but that the gun with uniform twist had a higher muzzle velocity and consequent length of range.‡

Table showing the Effect of the Employment of Uniform or Increasing Twist on Muzzle Velocity.

Spiral, 1 in 40 calibres.	Charge of powder, R.L.G.	Weight of projectile.	Muzzle velocity.
	lbs.	lbs.	f.s.
Increasing twist ...	30	179	1303·3
Uniform twist.....	30	179	1338·6

The Ordnance Select Committee stated "that the supposed advantage of the increasing spiral is, that the projectile having, at the moment of leaving its seat, only to move directly forward, gets away from the powder charge more readily than when—as in a gun with uniform spiral—it is forced simultaneously into rotatory motion. Somewhat more of the powder is therefore consumed before the shot moves in the latter than in the former case, and therefore the total force acting on the projectile during its passage through the bore is somewhat greater, and hence a somewhat greater muzzle velocity."

But this would hardly account for all the difference of velocity observed. The friction between the driving edges of the studs and the sides of the grooves in the gun is greater in the increasing than in the uniform twist for the same angle of spiral at the muzzle; for, on referring to the table at p. 41, giving the total pressure on studs (1) in uniform (2) in increasing twist, it will be seen that although the maximum pressure on the studs at any point in the bore is less in the increasing than in the uniform twist, yet the aggregate of the pressures is greater in the increasing twist, and consequently the friction resulting therefrom is greater in the increasing than in the uniform twist. This friction absorbs some of the work done by the charge of powder, and a lower muzzle velocity results. The small loss of muzzle velocity in consequence of the employment of increasing twist, is, in the opinion of practical artillerists, more than counterbalanced by its advantages in other respects.

* *Vide* "Treatise on the Construction and Manufacture of Ordnance in the British Service," p. 55.

† *Vide* p. 40, note.

‡ *Vide* "Proceedings, Ordnance Select Committee," Vol. IV. p. 252.

KRUPP'S

PATENT PROTECTED NON-RECOIL SYSTEM.

CONTRIBUTED BY

MAJOR E. MAITLAND, R.A.

The indefatigable German gun-maker is now busy in pushing on a new device which he considers likely to prove a decided advance in the practical manipulation of standing guns. It is still quite in the experimental stage, and has as yet been tried only with light pieces, but the success already attained is considered by Krupp to warrant great expectations.

The object of the system is the complete protection of the gun detachment and of the gun itself, except at the muzzle. It is also supposed to ensure accuracy of aim for a continuous series of rounds. The general idea is that the gun shall pivot at the muzzle in a ball and socket joint, fixed into the armour of a casemate, entirely closing the port and preventing recoil. Krupp claims that when once the gun is laid true on the object, it can be fired any number of times without recoiling, jumping, or otherwise changing its position or direction in the least; so that all error in shooting due to inaccuracy of laying is prevented when once the right direction is secured.

The drawing (Fig. 1) shows a section of a casemate for a 6-in. gun. The muzzle is enlarged to form a ball, *A*, which plays in a socket consisting of a steel port plug, *B*, into which is screwed a wrought-iron cylinder, *C*, holding the ball of the muzzle firmly in the socket. On each side of the gun the trunnion, *D*, travels up and down a carrier, *E*, in which a slot is cut for the purpose. This carrier is fitted with a hollow-soled truck, *F*, which permits the carrier to pivot on the racer, *G*, and so to accommodate the arc travelled through by the trunnion, when elevation is given, to the straight slot in the carrier. The truck also moves along the racer, *G*, when the gun is traversed.

The casemate is composed of a thick wrought-iron plate, *H*, in front, supported by strong box girders, *K*, and roofed with thin wrought-iron plate, *I*. The lower portion is made of cast-iron, *J*. It is protected from the enemy's fire by a glacis of concrete, *L*, in which is embedded a

I.

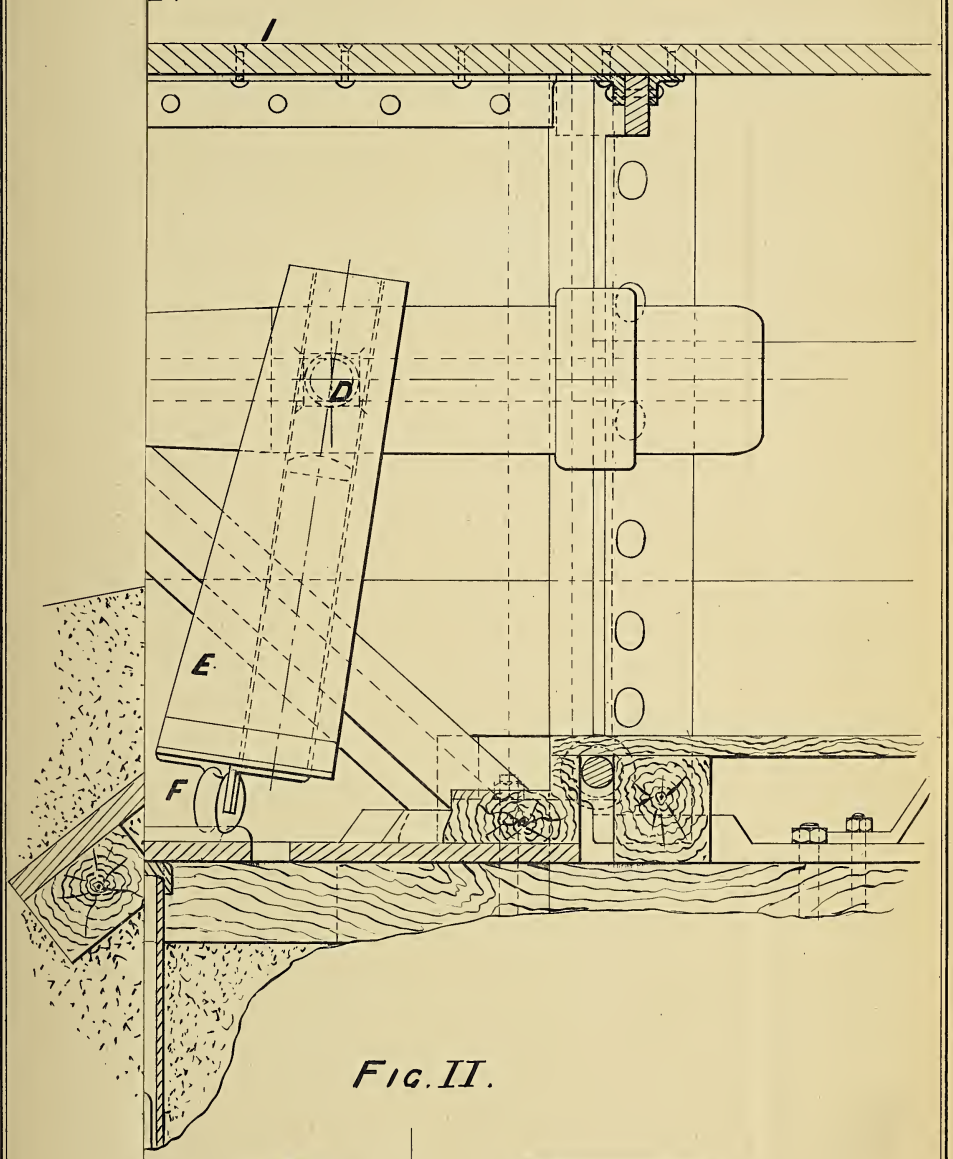


FIG. II.

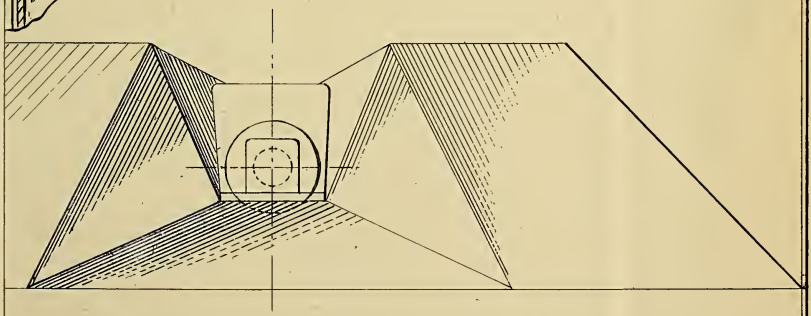


FIG. I.

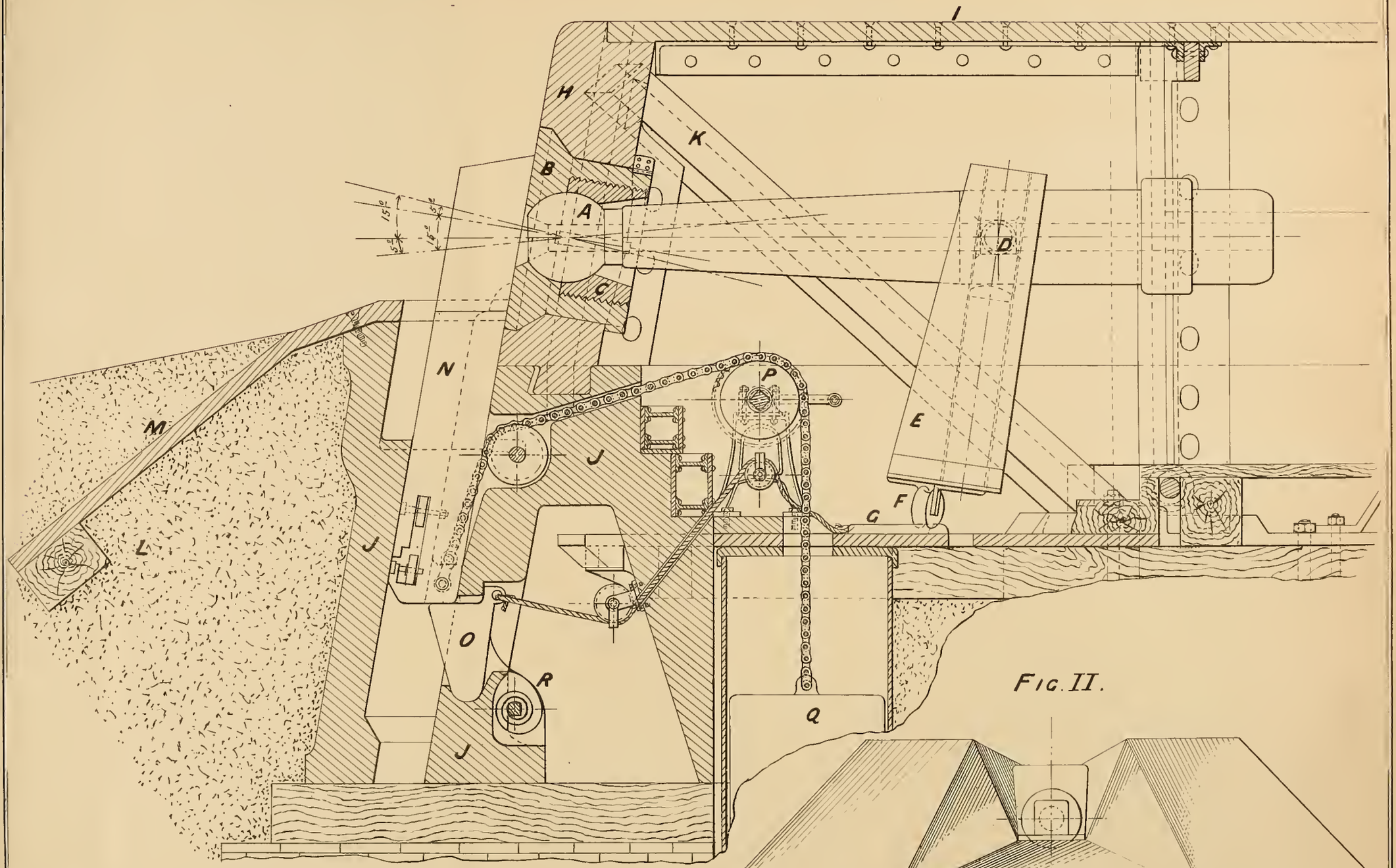
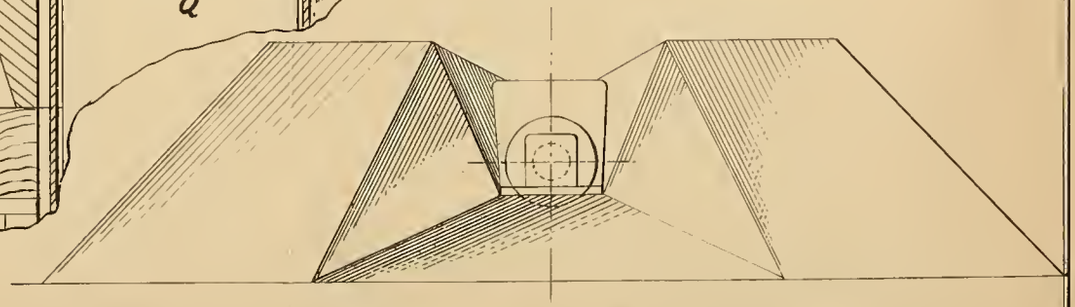


FIG. II.



wrought-iron glacis-plate, *M*. A wrought-iron shield, *N*, covers the muzzle of the gun when not firing. It rests on a trigger, *O*; so that when the gun is ready to be fired, the wire rope draws back the trigger and the shield falls. As soon as the gun is fired, the shield is raised by the winch, *P*, acting in aid of the balance weight, *Q*, and the trigger is forced back to its place as a support by the spring *R*.

The sides of the casemate are built up of brick, covered with wrought-iron plates. They are all sloped to permit shot to glance off without penetrating, as shown in Fig. 2.

It does not seem to be worth all this expense and complication to protect a 6-in. gun, and it may be assumed that Krupp is merely experimenting on a small scale, preparatory to mounting powerful guns in the same way. As regards the probable success of the system, it is too soon to speak with any certainty, and so many strides have been taken of late years in both offence and defence that it would not be prudent to condemn anything brought forward by gunners and engineers of such ability as those of Germany. At the same time, it seems that a great deal of strength would be required to hold, say, one of our 38-ton guns, when launching a projectile having an energy of 14,000 ft. tons.

Krupp considers that when this system is perfected, the doom of muzzle-loaders will be sealed; and if it should prove thoroughly successful, and should be quite inapplicable to muzzle-loading ordnance, it would no doubt be a strong argument for the employment of breech-loaders in certain positions. There is evidently, however, a good deal more to be done before this consummation is arrived at, and the system possesses one disadvantage which may possibly prove fatal to it. The principle of laying the gun is similar to that recently brought to great perfection by Capt. Watkin, whereby the guns are elevated and directed in accordance with instructions given by telegraph from the look out. The gunners know nothing of what they are firing at; they simply train the gun to a specified graduation of an arc on the floor, and give a specified quadrant elevation. This answers exceedingly well, as long as nothing goes wrong with the communications; and with us, if this should unfortunately happen, no very great damage is done—the No. 1 looks over the gun at the object, aims at it as well as he can in the smoke, guesses its distance, gives his elevation accordingly, and fires. With Krupp's system, on the other hand, a failure in the communication appears to stop the fire of a whole battery of guns; for it may probably be assumed that decent practice can scarcely be made by looking *through* a gun. It may be that such practical artillerists as the Germans have obviated this difficulty, or perhaps consider it of little value. In either case the new system is certainly one to be watched, with a view to our own profit, if it should turn out well.

FEBRUARY, 1877.

ACCOUNT OF AN EXPEDITION UP THE BOLAN PASS TO KHELAT TERRITORY, WITH MAJOR SANDEMAN, POLITICAL AGENT.

BY

CAPTAIN H. G. YOUNG, R.A.,

(Commandant No. 2 Mountain Battery, Bombay Presidency.)

[PART II.]

Major Sandeman's Mission to Khelat.

It will be remembered that at the end of Part I. half of the military escort were at Khelat with Major Sandeman, and the remainder at Garanee or Zearut—the former giving the name to the stream, the latter to the valley and village where the camp was pitched. On the 12th August 1876, after striking camp, this portion of the escort marched at 5.15 a.m. through the Zearut and Khelat valleys, 7 miles, and pitched camp at a place called Koing in the Khelat valley, some 2 miles from the town of Khelat. This march occupied exactly 2 hours. Khelat is the chief residence of the Khan, and is the capital of Beluchistan. It consists of a town surrounded by mud walls built on the slope of a hill some 200 ft. (at the top) from the ground. On the top of this hill stands the palace and citadel, in which the Khan resides. The place is very weak in defence and liable to capture, as close to the town is another hill from the top of which a clear command over the town is obtained. No one is permitted to enter the fortifications; but what ordnance exists is both ancient and unserviceable. The following description of Khelat is taken from Masson's book.

Khelat has three gates; the northern one is called the Mustung Gate, the eastern the Dil Dar Gate, and the southern the Gil Khan Gate. Adjoining the latter is a triangular outwork, called the Sanghar, entered by a gate close to that of Gil Khan. There are no houses in the Sanghar—formed by the continuation of the western wall (along the ridge on the eastern side of which the town is built), and by another wall carried from it to the gate of Gil Khan. At the apex is a large town. The work was probably erected to protect the Babi suburb lying beneath it, and to remedy its occupation by an enemy. On the western front, in the centre, stands the Miri, or citadel palace.

Outside the town, which is in a very dirty state (apparently no attempts are made to clean it), is a fruit and flower garden belonging to the Khan. In this garden are some ducks, that were formerly presented

to the Khan, and the only ones in Beluchistan. Fowls are the only poultry procurable. Outside the gardens are some tombs of former Khans, where the present Khan goes to worship every Friday. The escort force went into standing camp, awaiting orders; for though the object of the expedition (the opening of the Bolan Pass to free and safe traffic) has been successfully accomplished, the heat in the plains will not yet admit of the return march of the troops; and owing to the overflow of the river Indus, the station of Jacobabad is surrounded by water. In proof of the present safety of the Bolan Pass, a single troop of the Sind Horse escorted £10,100 of treasure for the payment of the troops from Jacobabad to our camp. Khelat is about 7,100 ft. above the sea level. Climate dry and cool; the nights very cold. On the 22nd August a change occurred in the weather; violent thunderstorms, accompanied with rain, burst over the camp, and the temperature fell considerably. This weather continued till the 1st September, when the rain ceased, followed by white frost, the thermometer falling to 31° at night; but a few days after it got quite warm again, the thermometer at night rising to 47°—a very trying climate. During this march, with a view to getting something like an idea of the correct time, I started a rough sun-dial, consisting of a straight stick, 3 ft. long, placed on a level with the ground. (The perpendicular was obtained with a plumb-line.) Of course the shortest shade from this stick gave noon, and the direction of the shade from the magnetic N. and S. line gave, as a rule, the variation. Some of the readings or observations of this sun-dial (3-ft. stick) may be interesting. They are all taken at noon, except when otherwise notified.

	ins.		ins.
21st May	$5\frac{1}{2}$	30th June	$4\frac{1}{10}$
3rd June	$4\frac{1}{10}$	6th July	$4\frac{2}{5}$
10th "	$3\frac{9}{10}$	10th "	$4\frac{3}{5}$
21st " ..... (longest day).	$3\frac{7}{10}$	1st Sept.	$14\frac{3}{10}$

A curious coincidence occurred in the observation taken at noon on the 6th September; the shade exactly covered the magnetic N. and S. line, and on taking another observation at 8 a.m. on the 7th September (the next day), the shade (length 6 ft. 4 ins.) coincided with the magnetic E. and W. line. On the 21st September (equinox) took two observations—one at 8 a.m., when the shade measured 7 ft. 11 ins., and a second at noon, when it measured $20\frac{2}{10}$ ins.

Nothing of importance occurred till the 14th October, on which date Colonel Colley, C.B. (Military Secretary), and Major Upperton (interpreter), arrived from Simla, bearing despatches from the Viceroy to Major Sandeman and the *Khan*. On their arrival, the Khan fired a salute of eleven guns from the palace. I may here mention that the above-named officers brought a three-dozen case of champagne—a present from the Viceroy to our mess. The wine was excellent, and the compliment fully appreciated. On the morning of the 18th October Colonel Colley reviewed the Khan's troops present at Khelat. They consisted, apparently, of about 700 infantry, 200 cavalry, two mountain guns on camels, and a splendid corps of baggage camels. (The Khan

afterwards stated that he had 1600 troops on the parade, but this was an exaggeration). The usual salute was given, and the troops marched past in slow and quick time, in column of troops and companies, formed line, and advanced to the general salute. They then filed past to quarters. The marching was steady, the men being armed with muzzle-loading muskets. On the afternoon of the same day, Colonel Colley held a grand durbar in the palace, at which all our European and native officers were present. The despatches were opened and presented to the Khan, containing invitations for him to meet the Viceroy in December at Jacobabad, and to attend the grand durbar at Delhi in January. Orders were then given regarding the movements of the escort, from which it appeared that Beluchistan and Cutchee were to continue to be occupied by British troops. The 3rd Sind Horse received orders to march on Dadur, in Cutchee (*vide* Part No. I.), and left standing camp on the 22nd October, proceeding *viâ* the Bolan Pass (of which Dadur is the entrance). The 4th Punjab Sikhs were directed to march to Quetta (the head of the Bolan Pass), and hut themselves there for the winter. They left standing camp on the 23rd October. The rest of the escort, consisting of a wing of the 30th Native Infantry and my half battery, were directed to form the personal escort of the Political Agent, and to proceed with him, on a date to be named hereafter, down the Moola Pass to Gundava, in Cutchee, with the Khan. As the escort is now broken up, I shall confine my future remarks to the movements of the personal escort, giving a description of the line of march down the Moola, from Khelat to Gundava. Colonel Colley and Major Upperton, attended by Major Sandeman, left Khelat on the 19th October, and Captain Wylie (Political Assistant) remained in political charge of Khelat. I shall once more adopt a journal form, as most suitable.

1*st November*, 1876.—Struck camp, and at 6 a.m. commenced our march to Rodinjo; distance 15 miles. Arrived at noon, but we halted 55 minutes on the road. Soon after starting we went over the lower range of hills south of Khelat, and then struck off S.W. and at once entered the Rodinjo valley, which is about two miles broad, enclosed on either side by high ranges of hills. The valley is uncultivated, and we frequently crossed the dry bed of a river. Rodinjo is a small hamlet, with a few trees scattered about. The water is supplied from a brook that runs past the encamping ground. Soon after pitching the tents a severe sand storm burst over the camp.

2*nd November*, 1876.—At 6 a.m. commenced our march to Gundagon (marked Surmasing on the map). Made camp at 11 a.m., having halted 40 minutes on the road. The route lay along the Rodinjo valley till within three miles of Gundagon, when we turned off to the right over a low range of hills, and descended into Gundagon. The road along the Rodinjo valley (which increased to 5 miles in width) was level and easy marching, and we crossed the same river as yesterday three or four times. None of the natives can give the name of this river—possibly because it remains dry, except on the rare occasions of

a mountain torrent. The encamping ground of Gundagon is on the bank of this river bed. The place is a regular wilderness; not a house or tree near the place, and there were no supplies. A few pools of water in the river bed supply the water. After pitching camp we got the benefit of sand storms again.

3rd November, 1876.—At 6 a.m. commenced our march to Sohrab; distance 12 miles. Arrived at 10 a.m., having halted on the road 20 minutes. The route lay over very undulating ground; the Rodinjo valley decreasing in width as we progressed, and at Sohrab the chains of hills on either side approach close to one another, with a narrow gap between. Sohrab gives the name to a number of orchards and small villages scattered about. There are a few supplies, and very good water from a brook running past the encamping ground.

4th November, 1876.—Halted at Sohrab.

5th November, 1876.—At 6 a.m. commenced our march to Anjira; distance 14 miles. Arrived at 10.45 a.m., but halted on the road 45 minutes. The road to day was very hard and stony; a steady descent (we are already 500 ft. lower than Khelat, and out of the range of snow). The route wound round a series of hills, and eventually led into the Anjira valley. Anjira is a desolate spot, consisting of one mud building, and not a tree is visible. There are no supplies, but fair water from a running stream on the encamping ground.

6th November, 1876.—At 6 a.m. commenced our march to Bopoh; distance 12 miles. Arrived at 10.45 a.m., but halted on the road 35 minutes. The road first led for 4 miles across the Anjira valley to the bed of the Moola river (which rises a few miles above Anjira) and here we entered the outer range comprising the Moola Pass. Our route then followed the river, either by the bank or along the bed, and in a few places we crossed some shallow water. The road all along was very rough and stony, making the marching difficult, but practicable for all arms. About two miles from Bopoh we turned from the river to our left, and on arrival there pitched camp. Bopoh consists of a small village, built amongst some fruit trees and under a high hill. It lies very low, and is invisible till you actually approach it. There are no supplies, but fair water from a brook running past the encamping ground. The temperature has become much milder. During this march we descended 800 ft. by the aneroid, and are 1300 ft. below Khelat.

7th November, 1876.—At 6 a.m. commenced our march to Pissibent; distance 11 miles, but halted on the road 35 minutes. Arrived at 10.50 a.m. After leaving Bopoh, the road followed the Moola river round a series of hills for some 8 miles, when it enters the Moola Pass proper through a defile about 15 yds. broad, with steep hills on either side some 250 ft. high. The road then runs along the stony bed of the river for a mile, when a fair amount of running water appears from springs in the hill side. The road follows the river bank, the water being frequently crossed, varying in depth from 1 to 3 ft., with

a rapid current. The encamping ground is on the left bank of the river—open ground, without a tree or house, and of course no supplies. During this march we descended 600 ft. more. On reaching camp, one of our officers went fly fishing, and caught several *mahseer* (Indian trout), running up to a pound; he also shot some wild duck and *chikor* (Indian partridge). This pass is quite a toy one compared with the Bolan, which is much broader and grander than the Moola. In the evening a thunder storm broke over the camp, accompanied with light rain. The lightning was very brilliant, and the peals of thunder among the hills grand. The river rose 3 ft., but the water ran off in a few hours. Sky clear at 11 p.m.

8th November, 1876.—At 6 a.m. commenced our march to Goorumabad; distance 11 miles. Arrived at 11 a.m., having halted on the road half-an-hour. The first 8 miles of the route lay along either bank of the river, over which we repeatedly crossed, and though the current was running strong, owing to the recent rain, we rarely found over 2 ft. of water at the fords. The remaining 3 miles of the road passed through a dense jungle, bushes and stunted trees being numerous. The camp was pitched on a piece of jungle ground (that had been cleared) above the left bank of the river. There is a small village, about a mile from the encamping ground, that afforded us a little milk but no other supplies. Forage and firewood are, however, plentiful. During this march the pass opened out to fully 500 yds., but the route we traversed was impassable for other than mountain guns. Field and horse artillery should always march up the Bolan Pass. The battery sustained a great loss during this march. My Subedar (senior native officer) died in a litter just before entering camp. He was attacked with disease of the kidneys just before our march from Khelat, and having only a native apothecary with a hospital void of medicines, but little could be done for the patient. He had served the Government 46 years, and fought on our side in the Indian mutiny and Persian war, both of which decorations were in his possession. Though 70 years of age, he cheerfully joined this expedition in hopes of more fighting; and I cannot resist the temptation of pa[illegible]g a tribute to a loyal servant of our Government, and to one who as a man and an officer had earned my respect and esteem. Being a Hindoo by religion, his remains were burnt by the men of the battery. During the night, very heavy rain fell and soaked all the tents; consequently on the *9th November* 1876, we could not strike them till 12.30 p.m., when we commenced our march to Pusht Khana; distance 8 miles. Halted a quarter-of-an-hour on the road and arrived at 3.20 p.m. During this march we descended 550 ft. The road as usual traversed either bank of the river, over which we frequently crossed. The encamping ground was an open spot; no village nor any supplies.

10th November, 1876.—At 6 a.m. commenced our march to Nur; distance 12 miles. Halted on the road half-an-hour and arrived at 11 p.m., having descended 900 ft. The road lay all the way along the river bed, and the loose shingle and boulders made it very heavy marching. We crossed the river more than twenty times, and in some places the water

was $2\frac{3}{4}$ ft. deep. The hills have now attained an altitude of about 600 ft., and stand out grand and peaked, the outer surfaces being almost perpendicular. The encamping ground is again an open spot without any village or supplies.

11*th November*, 1876.—Remained halted at Nur.

12*th November*, 1876.—At 6 a.m. commenced our march to Peer Lakha; distance 6 miles. Arrived at 8.45 a.m., having made no halt. We descended 400 ft. The road lay all the way along the river bed, and was very heavy (over loose shingle). During this short march we crossed the river twenty times, and in some places it was nearly 3 ft. deep; my ammunition boxes just escaping. We traversed one of the grandest parts of the pass—numerous chains of high rocks, collected together from various directions, the outer surfaces being perpendicular and the average height fully 500 ft. The camping ground is a rice swamp, and near it is a mosque, a few huts, and trees. Frewood in abundance, but no supplies.

13*th November*, 1876.—At 6 a.m. commenced our march to Hatajee; distance 9 miles. We halted on the road half-an-hour and arrived at 9.50 a.m. The first 4 miles were along the bed of the river (over which we crossed eighteen times), and the remaining 5 along a stony plateau; very heavy marching. The pass here opens out, being nearly a mile wide in some places, and the heat is increasing daily. We descended 530 ft. Hatajee consists of a few mud huts and stunted trees, and lies over the left bank of the river. No supplies, but forage and firewood plentiful.

14*th November*, 1876.—At 6 a.m. commenced our march to Paneewunt; distance 12 miles. Halted on the road 20 minutes and arrived at 10.30 a.m. The road lay all the way along the river bed, over loose shingle and boulders, making the marching both difficult and harassing. The pass continues very open, and signs of vegetation and cultivation appear in the valleys. We descended 520 ft. The encamping ground is above the right bank of the river, without a village or any supplies.

15*th November*, 1876.—At 6 a.m. commenced our march to Nowlung; distance 8 miles. Halted on the road half-an-hour, and arrived at 9.50 a.m. The first 5 miles, to a place called Kahoo (which consists of a few mud huts, and is generally selected for the camping ground), were along the bed of the river, over loose shingle and boulders—by far the hardest marching we have had; the river, too, over which we crossed very often was running very strong, and averaged $2\frac{1}{2}$ ft. in depth at the fords. After passing Kahoo, the road runs for about a mile over hard cultivated ground, and then ascends a stony plateau for another 2 miles (easy marching), when it descends to the river bed, over which we crossed and camped on the left bank. The camping ground is on the bed of the river. No village nor supplies. The pass here nearly ends, the hills being scarcely over 200 ft. high. During this march we descended 280 ft.

16*th November*, 1876.—Halted at Nowlung. In the afternoon

Mr. Furnivall (Under Secretary to Government, Railway Department), joined our camp. He has been up the Bolan Pass and down the Moola regarding a railway, and appeared to prefer the Moola.

17*th November*, 1876.—At 6.15 a.m. commenced our march to Pir Chutter; distance 7 miles. Halted on the road a quarter-of-an-hour, and arrived at 9.30 a.m. We descended 225 ft., which brought us down to 645 above sea level, having started from 7100 ft. Directly on starting, the road entered a narrow defile about 15 yds. wide, though it increased afterwards to some 150 yds., over very heavy shingle and large boulders, and crossed the river eleven times. The water in this defile is fed from all the hill streams, and rushes like a mill race. In some places it was up to the mule girths, and the ammunition boxes only just escaped. This defile extends for about 3 miles, narrowing again at the end, with which ends the Moola Pass proper. The road then ascends to the right, over a plateau of stones, for another mile, when it descends to the river bed, when the Moola river is crossed for the last time (soon after, it disappears entirely underground). The road then ascends another plateau to the left, and runs partly over stones, sometimes over cultivated ground, round low hills, about 3 miles to Pir Chutee. The encamping ground is very pretty, containing numerous palm trees, and it is covered with green grass (the first we have seen) and my mules cropped it eagerly. The water is supplied from a running brook, clear and good. There are a few huts about, but no supplies. Near the camping ground is a mosque and tomb, also a tank full of fish, fed by the priests. The trout fishing ended at Nowlung. After breakfast, Mr. Furnivall and Captain Wylie (Political Assistant), rode on to Gandava, to meet Major Sandeman.

18*th November*, 1876.—At 6 a.m. commenced our march to Kotree; distance 8 miles. Halted on the road half-an-hour, and arrived at 9.30 a.m. The first 3 miles of the road lay over low ranges of stony hills, past a mosque with a tomb and grave yard (all to the right), after which the route descended to the plains, and we traversed a low jungle to Kotree—which is a large town, fortified with a mud wall and towers at the corners. Supplies of all kinds are procurable. The encamping ground is open, with a few bushes and palm trees scattered about; soil sandy, and good water from a running brook. We found some mess stores awaiting our arrival, and very welcome they were. We descended 110 ft.

19*th November*, 1876.—At 6.5 a.m. commenced our march to Gandava; distance 7 miles. Halted a quarter-of-an-hour on the road, and arrived at 8.20 a.m. The road lay all the way through a jungle, over hard sandy soil, and we crossed the Nane river. Gandava is a large town, full of supplies, and the camping ground is large, dry, and open—some 2 miles from the town. The elevation is only 10 ft. lower than Kotree. On arrival, we found Major Sandeman encamped a mile from our camp.

20*th November*, 1876.—Halted at Gandava.

21*st November*, 1876.—Halted at Gandava. Colonel Nutthall, commanding the Sind Frontier Force, arrived yesterday evening from Jacobabad, and came to look at us this morning. The Khan of Khelat marched in this morning with great pomp, at the head of his army (three infantry regiments, two of cavalry, and three mountain guns, drawn by bullocks), colours flying, the band playing "Home sweet Home," and the guns firing a succession of salutes. The whole of the troops were miserably clad, and made a bad show. The bridles of the cavalry consisted of rope, and the infantry were armed with matchlocks. The gun detachments consisted of four men each. The Khan was dressed in a gold helmet, gold tunic, blue breeches with a broad red stripe, and patent leather boots with silver buckles. Major Sandeman went out to meet him, and escorted him to the palace in the town of Gandava.

22*nd and* 23*rd November*, 1876.—Halted at Gandava. On the evening of the 23rd a severe thunderstorm, accompanied by some very smart showers of rain, burst over the camp.

24*th November*, 1876.—At 5.30 a.m. we commenced our march to Sanchee; distance 14 miles. Halted half-an-hour on the road, and arrived at 10.40 a.m. At first we skirted the town of Gandava and its numerous hamlets; then the road led almost due north, over the sandy plain of Cutchee. I was much surprised to see that it had been cultivated in parts, as water is very scarce. Sanchee is a large village, and supplies of all kinds are procurable, but the water is very indifferent.

25*th November*, 1876.—At 6 a.m. commenced our march to Moochee; distance 9 miles. Halted on the road 20 minutes, and arrived at 9.20 a.m. Soon after starting we found ourselves floundering in some black mud, but quickly hit off the track which led over the sandy desert for 5 miles, and then for a mile through some cultivated ground. This brought us to the village of Budelar. The road then lay for 3 miles through a thick jungle of grass to Mochee—which is a small village, affording a few supplies, but the water is bad and the encamping ground very confined.

26*th November*, 1876.—At 6 a.m. commenced our march to Arain; distance 7 miles. No halt was made, and we arrived at 8 a.m. Two miles from Moochee we passed the village of Gul Mahomed, and the road went alternately over cultivated ground and sandy desert. The whole of this desert might be richly cultivated, as during the flood season it is all under water, much of which could be collected by artificial drainage; and as the Khan of Khelat takes one-third of every crop grown, by way of a tax, it is a matter of surprise that he does not encourage cultivation more than he does. No doubt the previous unsettled state of the province and constant raids prevented it; but if, as is reported, all will be quiet in the future, there is no reason why the arid plains of Cutchee should not be one mass of rich vegetation—a boon to the traveller in every way. A survey for a road, telegraph, and future railway has already commenced, and probably the day is not

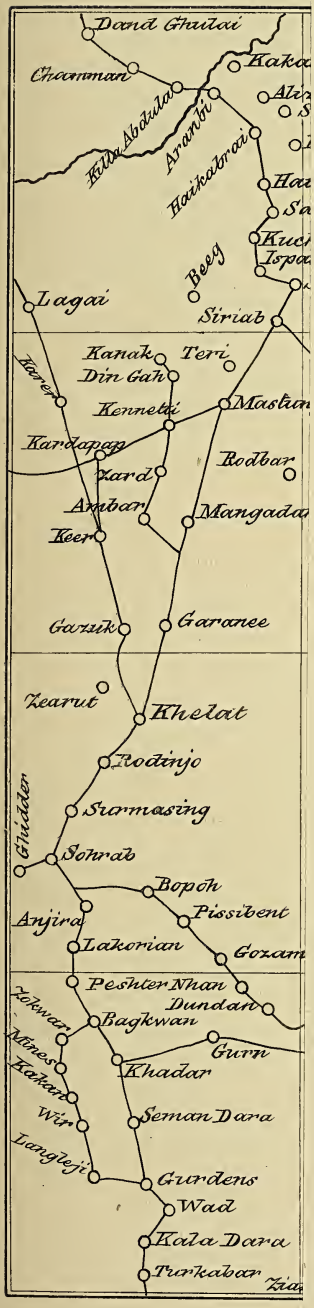
very distant when towns and villages will appear in the maps in place of the large tracts marked "desert." Arain is a small village, and affords numerous supplies; but the water from wells (our first experience of them since leaving Khelat), is both muddy and bad.

27*th November*, 1876.—At 6.15 a.m. commenced our march to Laloo; distance 7 miles. Made no halt on the road, and arrived at 8.30 a.m. The road all the way was over loose sand, and heavy marching. Four miles after leaving Arai we passed Jalan Khan—a large town, fortified with the usual mud walls and towers at the corners. Laloo is a small village, and affords supplies. The water supply was obtained from some preserved rain water. The camp was pitched in a field under cultivation, at the express desire of the owner. Now that we are marching without any political officer, the country people appear far more civil and energetic in producing supplies.

28*th November*, 1876.—At 6 a.m. commenced our march to Haji-ki-Thahar; distance 14 miles. Halted on the road half-an-hour, and arrived at 10.45 a.m. The first mile of the road lay through cultivated ground, the large town of Bagh (*vide* Part I.) lying 6 miles to our right. The remainder of the road lay along the sandy desert. At 4 miles from Laloo we passed a very large graveyard and some mosques. Haji-ki-Shahar is a large walled town; but as a description of it was given in Part I., I need not repeat it. The recollection of the place is the reverse of pleasant, as it was here so many of the escort died of cholera last April.

29*th November*, 1876.—At 6 a.m. commenced our march to Mitree; distance 8 miles. We halted a quarter-of-an-hour on the road, and arrived at 9 a.m. The road lay along the sandy desert, but we crossed the Norwa canal twice by fords (once just after leaving Haji-ki-Shahar, and again about a mile from Mitree), and found 2½ ft. of water. On arrival, we found the 3rd Regt. of Sind Horse, and went into standing camp. The camp is pitched some 2 miles from Mitree—which is a large town, surrounded by mud walls, with the usual corner towers, and citadel, or "miri."

Here the Journal ends, with a few remarks. The escort left Jacobabad on the 4th April 1876, proceeded up the Bolan Pass to Mustung, and there went into standing camp. It moved on to Garanee (or Zearut) and again went into standing camp; proceeded to Khelat, once more went into standing camp, and finally moved down the Moola Pass to Mitree, into standing camp, to await further orders. As it is believed that the escort will remain here for some months, I will bring the narrative to an end. The number of marches made is 38, and the ground traversed 505 miles. Both passes have now been traversed by an armed British force with facility. The Bolan is, without doubt, the shortest and most easy, and capable of being converted into an excellent road for all branches of the service. Quetta, at the head, is already occupied by a wing of a native infantry regiment, and the question of permanently occupying that place with a strong British force is now


Dand Ghaikai
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Rodbar
Zard
Ambar
Mangadar
Keer
Garzuk
Garanee
Zearut
Khelat
Rodinjo
Surmasing
Ghidder
Sohrab
Bopoh
Anjira
Pissibent
Lakorian
Peshter
Nhan
Dundan
Bagkwan
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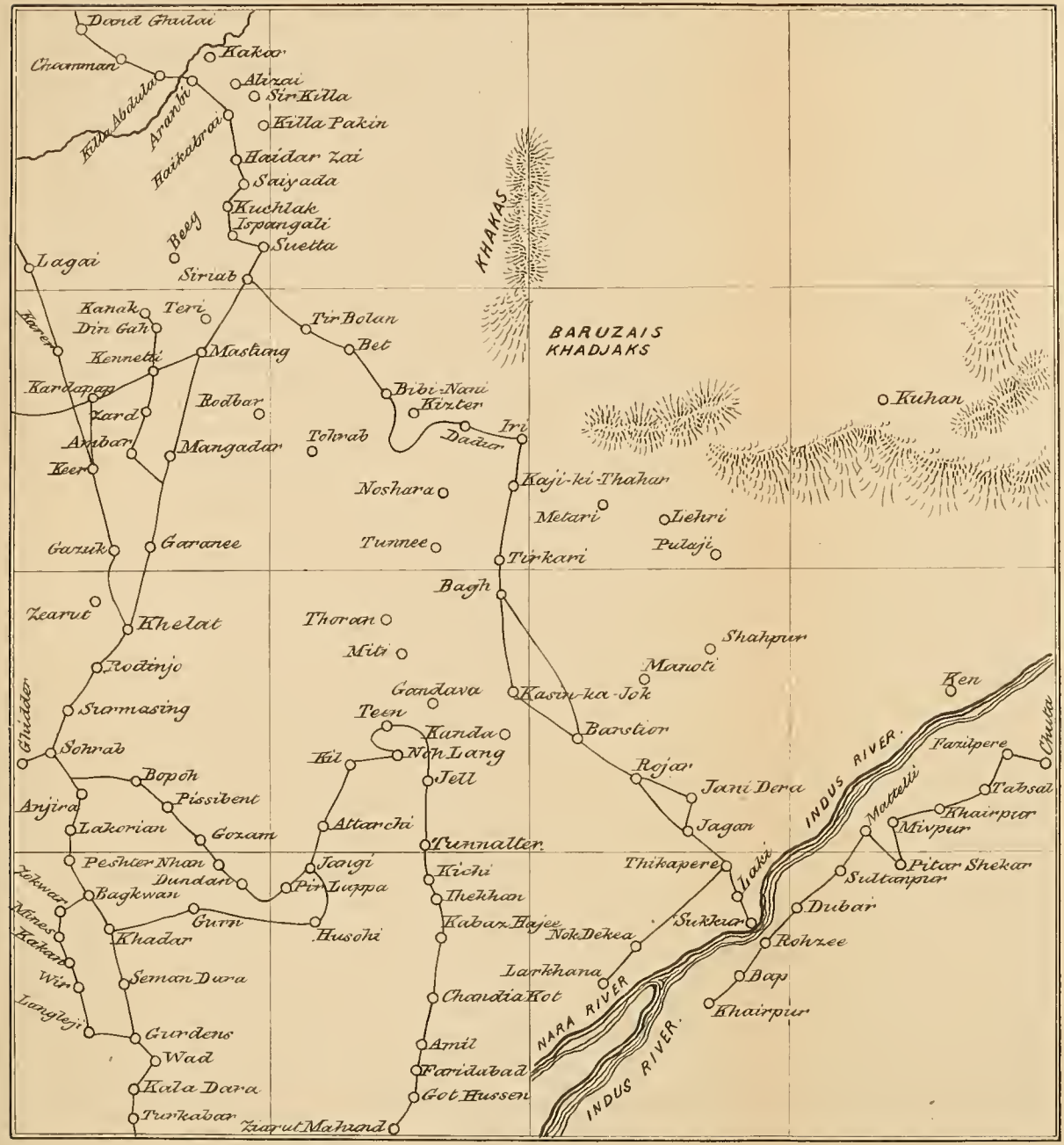
Khadar
Seman Dara
Wad
Kala Dara
Turkabar

ROUTE MAP.
BELUCHISTAN AND UPPER SIND.



SCALE OF ENGLISH MILES.

0 10 20 30 40 50 60 70 80 90 100

Copied from Route Map of M.r Masson's.
Camp Khelat
17th September 1876.

H. Grant Young
Capt.n R.A.

under consideration. Meanwhile, the Bolan is secure, with Quetta occupied at the top, and Mitree 13 miles from the mouth, and a strong reserve at Jacobabad, only five marches from Mitree.

In conclusion, I will give one more extract from Masson's book, regarding the town of Quetta (which, being the key of the head of the Bolan, is a most important place) :—

"Quetta (sometimes called Shawl, and the capital of the Saharawan District), an equivalent for 'fort,' is a small town of about 400 houses. It has a good bazaar, and is the most considerable place between Khelat and Kandahar, and also between Khelat and Ghaznee. It is surrounded by a cremated wall of some height, but inadequate, from its slight substance, to offer opposition to artillery. On a lofty mound within the walls is a ruined citadel, which yet affords a residence to the Governor of the town. There are two gates—one towards the east, called the Hanna; the other towards the west, called the Mustung. Soil rich and black, and abundant orchards full of fruit. Snow falls and settles for two months."

ANNUAL REPORT

AND

ABSTRACT OF PROCEEDINGS OF A GENERAL MEETING OF THE ROYAL ARTILLERY INSTITUTION, HELD ON MAY 24, 1877.

MAJOR-GENERAL C. L. D'AGUILAR, C.B., R.A., IN THE CHAIR.

---

1. The Committee of the Royal Artillery Institution beg to submit the Annual Report to the General Meeting of members.

2. There are now 1530 members of the Institution. (*Vide* table, Appendix "C.") During the past year 81 officers have joined the Institution, against 49 casualties from death and withdrawal.

3. The financial condition of the Institution is very good; the general credit amounting this year to £2676 13s. 4d. A detailed account of the expenditure and receipts, as well as a Dr. and Cr. statement, are attached. (Appendices "A" and "B.")

5. The subject selected for the Prize Essay of the year was "The Composition and Strength of a Siege Train required for the Attack of a Modern Fortress." Five essays have been received and submitted to the decision of Lieut.-General Sir Collingwood Dickson, V.C., K.C.B., &c., Colonel Owen, and Colonel Biddulph, who have been good enough to act as referees. Their decision will be communicated at the General Meeting, when the gold medal will be ready for presentation.

(The Report of the referees was read to the meeting, stating that they were unanimous in pronouncing the essay bearing the motto "L'Artillerie est tout dans les sièges et presque tout dans la guerre de campagne" the best of those submitted. On opening the sealed envelope, Major W. Kemmis was found to be the author of this essay.)

6. The French and German Classes held at the Institution have been well attended. There have also been Classes for Russian and Drawing. Drawing Classes have also been held at Aldershot and Sandhurst.

7. Lists of presentations during the year are attached. (*Vide* Appendices "D" and "E.")

8. The following changes in the Committee have taken place during the year:—

Colonel Younghusband.....	replaced	Colonel Aitken.
Lt.-Col. P. J. Campbell	"	Lt.-Col. H. Heberden.
" F. T. Whinyates	"	" W. G. Andrewes.
" W. N. Waller	"	" A. H. W. Williams.
Major E. J. Ward-Ashton	"	Major F. Duncan.
" W. H. Izod	"	" M. Elliot.
" F. Duncan	"	" T. S. Seccombe.
" M. F. Downes	"	" W. H. Izod.
Capt. C. Jones	"	" J. Ritchie.
" E. Clayton	"	" F. Lyon.
" G. A. French	"	Capt. H. S. S. Watkin.
Lieut. G. Mackinlay	"	Lieut. H. Torkington.

It will be the duty of the General Meeting to elect an officer to serve upon the Committee in the place of Lt.-Col. King, who has completed his three years.

The Committee for the current year will stand thus:—

PATRON AND PRESIDENT:

Field Marshal H.R.H. the Duke of Cambridge, K.G.

VICE-PRESIDENTS:

The Major-General Commanding the District.
The Inspector General of Artillery.
The Director of Artillery and Stores.
The Deputy Adjutant-General, R.A.

MEMBERS:

The Assistant Adjutant-General, R.A.
The Director of Artillery Studies.
The Assistant Adjutant-General, Woolwich.
The Secretary, Department of Director of Artillery and Stores.
Major-General F. M. Eardley-Wilmot, F.R.S.
" W. J. Smythe, F.R.S.
" J. H. Lefroy, C.B., F.R.S.

Colonel C. W. Younghusband.
Lieut.-Colonel P. J. Campbell.
" F. T. Whinyates.
" W. N. Waller.
Major M. F. Downes.
" Ward-Ashton.
" F. Duncan.
Major W. G. Brancker.
Captain C. Jones.
" G. A. French.
" E. Clayton.
" R. Hare.
" W. E. Denison.
Lieut. G. Mackinlay.

Major M. Le Fer Taylor, *Secretary and Treasurer.*

The Annual Report of the Committee was read to the meeting.

1. *Proposed by Colonel Shaw, seconded by Colonel Gosling:—*

"That the Annual Report, as read, be adopted."

Put to the meeting and carried.

2. *Proposed by Colonel Whinyates, seconded by Colonel Gosling:—*

"That the essay bearing the motto 'Via—vi,' placed second and very highly commended by the referees, be published in the 'Proceedings.'"

Put to the meeting and carried.

This essay was found to be by Colonel Wray, R.A.

3. *Proposed by Lt.-Col. King, seconded by Captain Dugdale:—*

"That should the number of essays submitted for competition for the gold medal exceed seven, and the referees be unanimous as to which of them is second in merit, a silver medal may be presented to the author, upon the special recommendation of the referees."

Amendment proposed by Major Stoney, seconded by Colonel Field:—

"That the award of the silver medal to the author of the second best essay be independent of the number of essays submitted."

Amendment proposed by Lt.-Col. Whinyates, seconded by Colonel Gordon:—

"That the question of awarding a silver medal to the author of the second essay be postponed for further consideration."

Last amendment put and negatived.

The previous amendment was then put and carried.

The original motion, with the limitation as to number omitted, viz.—

"That in the event of the referees being unanimous in their opinion as to which of the essays submitted for competition for the annual gold medal is second in merit, and upon their special recommendation, a silver medal may be presented to the author of such essay,"

was then put to the meeting and carried.

4. *Proposed by Colonel Gosling, seconded by Colonel Gordon:—*

"That Colonel Field be elected to serve upon the Committee, *vice* Lt.-Col. King, whose time has expired."

Put to the meeting and carried.

5. A letter was read from the D.-A.-Gen., R.A., dated 6th March, 1877, conveying the order of H.R.H. the Field Marshal Commanding-in-

ACT

L ARTILLERY INSTITUTION,

rch, 1877.

INCOME.

		£ s. d.	£ s. d.
hand, 31st March, 1876			512 3 11
g			139 6 4
Printed by R.A.I. Prize Essayists			21 0 0
raphy			9 17 8
			86 13 11
Diesmy			2 10 0
Photsold			251 5 5
Classtry and Picture Framing			48 14 8
Taxi	Entrance	77 0 0	
Lect	1869-70	0 10 0	
Libr	1870-1	0 10 0	
Mus	1871-2	0 10 0	
Instr	1872-3	3 8 0	
ptions	1873-4	5 4 0	1287 1 6
Carp	1874-5	11 19 6	
Buil	1875-6	32 10 0	
Furn	1876-7	1147 13 0	
Subs	1877-8	7 6 6	
Stati	1878-9	0 10 6	
Postery sold			199 15 10
Incie and Parcels			55 12 7
Wag hotographs and Lithographs			7 1 5½
W.Cds on £2000 Consols			59 5 0
Fire			
Cash			
			£2680 8 3½

NDING 31st MARCH, 1877. CR.

		£ s. d.	£ s. d.
Prin hand, 31st March, 1877			344 5 9
Clas onsols Stock, at 93½			1870 0 0
Boo	Books for Sale	15 0 0	
Carp	Stationery for Sale	22 10 0	
Wo of	Printing Paper	52 15 0	
Stat.	"Handbooks" (unbound)	4 13 9	130 18 9
Par	"Kane's Lists" do.	16 0 0	
W.C	Chemicals in Laboratory	20 0 0	
R.A	Printing	62 14 11	
	Photography	3 17 10	
	Classes	7 17 6	
	Taxidermy	1 10 6	
by	Books and Binding	58 15 5	
rs.	Carpentry	12 3 10	431 14 0
	Subscriptions	161 17 0	
	Stationery	76 9 2	
	Postage and Parcels	40 16 11	
	W.O. Photographs and Lithographs	5 10 11	
			£2776 18 6

J.

T.

APPENDIX.

A.

GENERAL ABSTRACT

OF THE

INCOME AND EXPENDITURE OF THE ROYAL ARTILLERY INSTITUTION,

From 1st April, 1876, to 31st March, 1877.

EXPENDITURE.

		£ s. d.	£ s. d.
Printing	Wages	162 0 6	
	Paper and Materials	292 1 0	
	Type and General Plant	21 8 11	577 17 2
	Wood Engraving	34 11 0	
	Lithography	67 15 9	
Dies for Gold Medal and Six Medals			186 8 6
Photography			22 1 9
Classes			180 12 4
Taxidermy			2 10 0
Lectures			16 16 0
Library, and Books for Sale			276 9 7
Museum			37 11 0
Instruments			30 0 0
Carpenter	Wages	20 3 8	114 3 6
	Materials	93 19 10	
Building new Printing Office (balance)			257 9 2
Furniture and Repairs			106 2 4
Subscriptions to Societies			4 4 0
Stationery			205 5 7
Postage and Parcels			88 0 9
Incidental Expenses			61 6 10
Wages to Clerks and Orderlies			147 4 4
W.O. Photographs and Lithographs			8 1 2½
Fire Insurance	R.A. Institution in £5000	12 10 0	13 18 6
	R.A. Observatory in £1000	1 8 6	
Cash in hand, 31st March, 1877			344 5 9
			£2680 8 3½

INCOME.

	£ s. d.	£ s. d.
Cash in hand, 31st March, 1876		512 3 11
Printing		139 6 4
Refunded by R.A.I. Prize Essayists		21 0 0
Photography		9 17 8
Classes		86 13 11
Taxidermy		2 10 0
Books sold		251 5 5
Carpentry and Picture Framing		48 14 8
Subscriptions: Entrance	77 0 0	
1869-70	0 10 0	
1870-1	0 10 0	
1871-2	0 10 0	
1872-3	3 8 0	
1873-4	5 4 0	1287 1 6
1874-5	11 19 6	
1875-6	32 10 0	
1876-7	1147 13 0	
1877-8	7 6 6	
1878-9	0 10 6	
Stationery sold		199 15 10
Postage and Parcels		55 12 7
W.O. Photographs and Lithographs		7 1 5½
Dividends on £2000 Consols		59 5 0
		£2680 8 3½

B.

DR. DEBTOR AND CREDITOR ACCOUNT FOR THE YEAR ENDING 31st MARCH, 1877. CR.

	£ s. d.	£ s. d.
Printing, Paper, and Materials	3 18 10	
Classes, Drawing Instruction	8 8 0	
Books and Periodicals	77 18 1	
Carpentry and Picture Framing	4 16 9	
Wood Engraving	1 13 0	
Stationery	0 17 3	
Parcels	2 2 4	
W.O. Photographs and Lithographs	0 1 7	
R.A. Mess and R.A. Canteen, Woolwich	0 9 4	
General Credit, 31st March, 1877	2676 13 4	
	£2776 18 6	

		£ s. d.	£ s. d.
Cash in hand, 31st March, 1877			344 5 9
£2000 Consols Stock, at 93½			1870 0 0
Value of Stock.	Books for Sale	15 0 0	130 18 9
	Stationery for Sale	22 10 0	
	Printing Paper	52 15 0	
	"Handbooks" (unbound)	4 13 9	
	"Kane's Lists" do.	16 0 0	
	Chemicals in Laboratory	20 0 0	
Owing by Members.	Printing	62 14 11	431 14 0
	Photography	3 17 10	
	Classes	7 17 6	
	Taxidermy	1 10 6	
	Books and Binding	58 15 5	
	Carpentry	12 3 10	
	Subscriptions	161 17 0	
	Stationery	76 9 2	
	Postage and Parcels	40 16 11	
	W.O. Photographs and Lithographs	5 10 11	
			£2776 18 6

Accounts examined,

J. DE HAVILLAND, Lt.-Col. R.A., and Colonel,

T. C. HIGGINSON, Major.

WOOLWICH, 5th May, 1877.

Chief that the following should be added as a footnote to the Rules and Regulations laid down for the guidance of the Committee :—

"His Royal Highness directs that the concurrence of the General Officer Commanding the Troops at Woolwich be obtained before any arrangements are made for holding Lectures or Readings in the Theatre of the Institution.'

6. The Committee recommended that a sum of money not exceeding £80 be granted from the funds of the Institution to pay off the amount due on the portrait of General Sir E. Sabine, K.C.B., R.A.

This recommendation was put to the meeting and carried.

C.

Statement showing Increase and Decrease of Members of the R.A. Institution during the year ending 31st March, 1877.

Ranks.	31st March, 1876.	Increase.			Total increase.	Decrease.				Total decrease.	31st March, 1877.
		Promotion.	Retirement.	New members.		Promotion.	Retirement.	Withdrawal.	Death.		
EFFECTIVE LIST.											
General and Regimental Field Officers	472	10	—	3	13	—	1	6	9	16	469
Captains	327	19	—	—	19	10	—	—	3	13	333
Lieutenants	480	—	—	74	74	19	—	5	5	29	525
Paymasters	8	—	—	—	—	—	—	—	1	1	7
Quarter-Masters	5	—	—	—	—	—	—	—	—	—	5
Riding-Masters	5	—	—	—	—	—	—	—	—	—	5
Surgeons-Major	3	—	—	—	—	—	1	—	—	1	2
Veterinary Surgeons	4	—	—	—	—	—	—	—	—	—	4
RETIRED LIST.											
General and Regimental Field Officers	88	—	1	—	1	—	—	4	4	8	81
Captains	37	—	—	—	—	—	—	—	1	1	36
Lieutenants	12	—	—	—	—	—	—	1	—	1	11
Quarter-Master	1	—	—	—	—	—	—	1	—	1	—
Surgeons-Major	5	—	1	1	2	—	—	1	—	1	6
Surgeons	3	—	—	—	—	—	—	2	—	2	1
Chaplain	1	—	—	—	—	—	—	—	—	—	1
HONORARY MEMBERS	47	—	—	3	3	—	—	4	2	6	44
Totals	1498	29	2	81	112	29	2	24	25	80	1530

D.

Presentations to the Library, &c.

Proceedings of the Zoological Society. Part IV., 1875; and Parts I., II., and III., 1876.	The Council of the Society.
Examination Papers R.M. Academy, Woolwich, February, 1876.	The Governor R.M. Academy.
Proceedings of the Institution of Mechanical Engineers, January, May, July, and October 1876	The Council of the Society.
Institution of Mechanical Engineers. General Index to Proceedings. 1847–73	

Return of all Letters or Memorials from Majors of Royal Artillery serving in India, complaining of the Mode in which the Royal Warrant of the 5th July, 1872, was carried out in India.	The Secretary of State for War.
Regulations for the Commissariat Department and Ordnance Store Department	
69 W.O. Photographs	
The Franco-German War, 1870–1. 9th Section, Part I.	
Extracts from the Proceedings of the Department of the Director of Artillery. Vol. XIII., Part IV., and Vol. XIV., Parts I. and II.	
Regulations for the Equipment of the Army. 1876	
Second Report of the Education of Officers, by the Director-General of Military Education	
5 Royal Carriage Department Lithographs	
5 " Gun Factory "	
9 " Laboratory "	
The Ottoman Empire and its Tributary States (excepting Egypt), with a Sketch of Greece. By Captain W. L. Cooke, 22nd Regiment	
The Armed Strength of the German Empire. Part I.	
The Armed Strength of the Netherlands	
3 Drawings of Artillery *Matériel*	Capt. Wisbech, Swedish Navy.
Hart's Quarterly Army List. October 1875, and April and July 1876	R.A. Library, Woolwich.
Archæological Sketches in Scotland. By Captain T. P. White, R.E.	Lieut. A. W. White, R.A.
Photographic Portrait of General Sir R. Gardiner, G.C.B., A.D.C. to Her Majesty the Queen, 1840	Col. L. Gardiner, R.H.A.
Proceedings of the United Service Institution of India. Vol V., Nos. 20, 21, 22, 23, 24, and 25.	The Council of the Society.
Journal of the Royal United Service Institution. Nos. 84, 85, 86, 87, and 88, Vol. XIX.	The Council of the Society.
History of "E" Battery, "D" Brigade, R.H.A., from 1820 to 1876. By Major Le Cocq, R.H.A.	The Author.
A Collection of Botanical Specimens made by the North American Boundary Commission	The Secretary of State for Foreign Affairs.
The China War of 1860. By General Sir Hope Grant, G.C.B., and Captain H. Knollys, R.A.	Capt. H. Knollys, R.A.
6 Water-Color Views taken during the North American Boundary Expedition. 1874–5	Major D. R. Cameron, R.A.
Map of the Yellowstone and Missouri Rivers, and their Tributaries	
Map showing the Line of Route between Lake Superior and Red River Settlements	
Map of "Nebraska" and "Dakota"	
Map of the United States, from the Mississippi River to the Pacific Ocean	

Russian Artillery Journal for 1876. 4 parts (Nos. 1, 2, 3, and 4), and Nos. 1 and 2, of 1877.	The Russian Government.
Russian Small-Arms Journal. No. 3, 1876 ...	
Minutes of Proceedings of the Institution of Civil Engineers. Vol. XLIII., 1875–6, Part IV.; Vol. XLIV., Parts I., II., III., and IV.; Vol. XLV., Part I.	The Council of the Society.
Fors Clavigera for May, June, July, August, September, October, November, December, January, February, and March	J. Ruskin, Esq., LL.D.
"Proserpina." Studies of Wayside Flowers. Part IV.	
"Deucalion." Parts III. and IV.	
Appendix to Ariadne Florentina. Six Lectures on Wood and Metal Engraving. By John Ruskin, LL.D.	
Journal of the Royal Geographical Society. Vol. XLV. 1875	The Council of the Society.
Proceedings of Royal Geographical Society. Vol. XX., Nos. 4, 5, and 6	
History of "A" Battery, "D" Brigade, R.H.A. By Captain G. E. W. Malet, R.H.A.	The Author.
Historical Records of the Regiments specified:— Horse Guards; 2nd, 3rd, 4th, 5th, 6th, and 7th Dragoon Guards; 1st, 2nd, 3rd, 6th, 7th, 9th, 10th, 12th, 13th, 14th, 15th, and 16th Dragoons ... 17th Lancers; 1st to 23rd Regiments of Foot; 31st, 34th, 36th, 39th, 42nd, 46th, 53rd, 56th, 61st, 67th, 70th, 71st, 72nd, 73rd, 74th, 86th, 88th, and 92nd Regiments of Foot, and Cape Mounted Riflemen...	The D.-A.-General, R.A.
Standing Orders, R.A., 1876	
Manual of Elementary Field Engineering	
Washington Astronomical and Meteorological Observations, 1873	The Council of the Smithsonian Institution.
Smithsonian Contributions to Knowledge. Vols. XX. and XXI.	
Pamphlet on the Importance of Industrial Education. By Major H. Le G. Geary.	The Author.
Records of "E" Battery, "E" Brigade, R.H.A. By Major Holberton, R.H.A.	The Author.
Report on the Circumstances attending an Explosion of Dynamite at Cymmer, Glamorganshire, on the 21st April, 1876	Major Majendie, R.A.
Report on the Circumstances attending an Explosion of Gunpowder at Herodsfoot, Liskeard, Cornwall, on the 12th May, 1876.	
Report on the Circumstances attending an Explosion of Fulminate of Mercury, at Hinks' Chemical Works, Small Heath, Birmingham, 14th May, 1876.	Major Ford, R.A.

15 Maps of different parts of India	The Secretary of State for India.
Taktik-Perizonius. 2 vols., and atlas.	Major W. G. Brancker.
Taktik-Waldstätten. 3 vols.	
Der Krieg von 1806 und 1807. 4 vols	
Carl von Clansewitz. Hinterlassene Werke. 3 vols.	
Der Antheil des Königlich Sächsischen armee corps am Feldzuge 1866 in Osterreich. 1 vol.	
Die Feldzüge der Yahre 1859 und 1866. 1 vol.	
Die Preuszische Kavallerie in der Campagne 1866. 1 vol.	
Der Gebrauch der Artillerie im Feld Kriege. Taubert. 1 vol	
Geographie Physique. Lavallèe. 1 vol	
Modern Tactics of the Three Arms. By General M. W. Smith	
Questions and Answers for the use of Non-Commissioned Officers and Men of Batteries of Horse and Field Artillery, armed with 9-pr. M.L.R. Guns of 6 cwt. By Lieut. J. C. Dalton, R.H.A.	The Author.
Recueil de Diplomes Militares Publié. Par M. Leon Renier	The French Government.
1 copy Universal Scale for Maps	Colonel Holmes.
Handbook of Artillery for the Auxiliary Artillery. By Major Downes, R.A.	The Author.
Prussian Fortress and Siege Artillery. Part IV.	The Director of Artillery.
Report by Special Committee on the Working of Heavy Guns. Trial of 38-ton Gun in the Experimental Casemate at Shoeburyness	
Report of Major W. Kemmis, R.A., on an Official Visit to Belgium, August 1876	
Notes on Moving and Mounting 35 and 38-ton Guns	
Final Report of Special Committee on the Question of adopting Means for the Prevention of Scoring in the Bores of Heavy Rifled M.L. Guns	
Narrative of the Operations of the British North-American Boundary Commission. 1872–6	Capt. Featherstonhaugh, R.E.
International Exhibition Philadelphia Catalogue, British Section. Part I.	H.M. Commissioners.
"Fog Signals." Correspondence and Reports in relation to the Construction of a Special Gun, and utilisation of Gun-Cotton for Fog Signal purposes; with an appendix on the subject of Experiments for Rockets	The Elder Brethren of the Trinity House.
Italy and Rome. By Lord Waveney, F.R.S.	The Author.
A Handbook on the Eastern Question. By Sir G. Campbell, M.P.	Eastern Question Association.
Official Catalogue of the United States International Exhibition. 1876	Major Noble, R.A.
Plates of the Effect of Firing at Forts Munro and Delaware	

Light Cavalry Outposts. By F. de Brack	Major Hale, R.E.
Professional Papers of the Corps of Royal Engineers. Vol. XXIII. 1876.	
Extracts from the Transactions of the Linnean Society of London. Second Series. Botany. Vol. I.	Lieut. Nelson, R.E.
A Primer for Garrison Artillery.....	Major Downes, R.A.
The Annual Address of the Victoria Institution for 1875–6	
Journal of the Transactions of the Victoria Institute. 1874. Vol. VIII., Nos. 29, 30, 31, and 32; Vol. IX., Nos. 33 to 39.	
Collections of a London Citizen	Major Stoney, R.A.
A Common-Place Book of J. Milton	
History of the Bengal Artillery. Vols. I. and II. By Major Stubbs, R.A.	The Author.
Catalogue of the Royal Engineer Libraries.....	Secretary R.E. Libraries.
Tegninger Uorsk-Marine Artillery *Matériel*	Norwegian Government.
Greenwich Magnetical and Meteorological Observations, 1874	The Astronomer Royal.
Report on the State of the Militia of the Dominion of Canada for 1876	Capt. de la C. T. Irwin, R.A.
Harvey's Sea Torpedo	Lieut. W. L. C. Gordon, R.A.
Lectures on Histology. By Quekett	

Books, &c., purchased.

Molesworth's Pocket Book of Engineering Formulæ.
An Elementary Treatise on Steam. By J. Perry.
Geometry of Three Dimensions. By G. Salmon.
Naval Powers and their Policy. By G. C. Paget.
The Ibis. Nos. 22, 23, and 24, Vol. VI.; Fourth Series, No. 1, Vol. I.
The Nautical Almanac, 1877.
The Birds of Europe. Parts XLVII., XLVIII., XLIX., L., LI., LII., LIII., LIV., LV., and LVI.
Technological Dictionary, in the English, German, and French Languages. Edited by A. Tolhausen.
Ganot's Physics.
Taktik der Feld Artillerie. By Von Hoffbauer.
Instructions in Fortification, Military Engineering, and Geometrical Drawing, at the R.M. Academy, Woolwich.
The German Artillery in the Franco-German War, 1870–1. Parts I. and II.
Fifth Report of the Royal Commission on Historical Manuscripts. Part I.
Chronological and Historical Chart of India. By A. Durtnall.
Monograph of the Sunbirds. Parts I., II., and III. By Capt. E. Shelley.
Introductory Text Book on Geology.
Correspondence respecting the Affairs of Turkey, and the Insurrection in Bosnia and the Herzegovina.
The Birds of Asia. Part XXVIII.
French-Spanish Dictionary. By Salon.
Russian Dictionary. By Rieff.
Les Armes à Feu Portatives Leur Origine. R. Schmit.
Ride to Khiva. By Capt. Fred. Burnaby.

A Course of Water-Color Painting ... }
" Painting in Neutral Tint } R. P. Leitch.
" Sepia Painting..... }
A Military Tour in European Turkey. By Major-General Mackintosh.
Encyclopædia Britannica. 9th Edition. Vols. IV. and V.
Lemprier's Classical Dictionary.
Twentieth Report of Her Majesty's Civil Service Commissioners, together with Appendices.
French Dictionary. By Contanseau.
Flügell's Dictionary (English and German).
Eastern Persia, 1870–2. Vols. I. and II. By Sir F. J. Goldsmid.
Troy and its Remains. By Schlumann.
Correspondence respecting the Conference at Constantinople and the Affairs of Turkey, 1876–7.
Correspondence respecting the Affairs of Turkey, 1876.
Elements of Machine Design. By Unwin.
Text Books of Science:—
Arithmetic and Mensuration. Merrifield.
Principles of Mechanics.
Qualatative Chemical Analysis. Thorpe and Muir.
Introduction to Chemical Philosophy. Tilden.
Quantatative Chemical Analysis. Thorpe.
Organic Chemistry. Armstrong.
Railway Appliances. Barry.

E.

Presentations to Museum.

10 Specimens of Birds, collected by the North American Boundary Commission	The Secretary of State for Foreign Affairs.
12 Type Specimens of Birds from Peru, collected by H. Whitely, Junior.	H. Whitely, Sen.
1 Platypus and 2 Bird Specimens from Australia. 1 Bird from Tasmania.....	Lt.-Col. McMahon, R.A.
2 Cases of Indian Birds.....	Mrs. Bazalgette.
A Wild Cat Skin (Lynx)	Farrier-Serjeant P. Morrisey.
Officer's Coatee of the Bengal Artillery, prior to 1804, worn by the late Lt.-Col. Glass	Capt. Glass, R.A.
A Glass Bottle found in the Redan	Surgeon-Major Perry.
Chinese Candles taken from one of the Temples in China	Presented by Col. R. Biddulph, R.A.
Indian Ghoorka Knife	Lieut. L. W. Parsons, R.H.A.
Double-Barrel Gun, made by a Native of Cashmere	Col. Hope, R.A.
Tiger's Skull.....	Lieut. H. Torkington, R.H.A.
14 Silver and 8 Copper Coins	Lt.-Col. G. G. Pearse, R.A.
9 Silver and 9 Copper Coins.....	Staff Serjt. Pinder, R.A.
12 Medals and Coins (various).....	Capt. H. W. Feilden, R.A.

List of Papers published in the "Proceedings" during the year.

On the Heavy 4-pr. Gun for Field Batteries, proposed by the Russian Artillery Committee. By Captain Paskevitch. (From the "Russian Artillery Journal" for July 1875.) Translated into Italian, and published in the "Giornale d'Artiglieria e Genio" for October 1875, and thence translated by Colonel H. H. Maxwell, R.A.

The 7^{c} Italian Field Gun (Bronze). By Colonel H. H. Maxwell, R.A.

The Next Step in Field Artillery Progress. By Lieut.-Col. Fox Strangways, R.A.

New (Wrought-Iron) Carriages, for Field and Siege Service. By Major W. Kemmis, R.A.

Short Notes on Erecting Portable Sheers in Cork Harbor for Lifting 35-ton Guns, 1875–6. By Lt.-Col. Denis-de-Vitre, R.A.

Précis of the Franco-German War. By Captain S. C. Pratt, R.A. Part I. Saarbrücken to Metz.

Account of an Expedition up the Bolan Pass to Khelat Territory, with Major Sandeman, Political Agent. By Captain H. G. Young, R.A. (Commandant No. 2 Mountain Battery, Bombay Presidency.)

On the Comparative Advantages of Time Fuzes and Percussion Fuzes in Shrapnel Shell, as shown by the Experiments at Okehampton, August and September, 1875. By Major F. Lyon, R.A. (Assistant Superintendent Royal Laboratory.)

Extracts from the Report by the Special Committee on Rifled Field Guns and High-Angle Fire on the Artillery Experiments at Okehampton, in August and September, 1875.

Results of Experiments made in the Royal Carriage Department (in May and September, 1876), to test the Relative Strength of Different Forms of Brackets and Axletrees for Field Gun-Carriages. Communicated by Major W. Kemmis, R.A.

Précis of the Franco-German War. By Captain S. C. Pratt, R.A. Part III. The War in the Provinces. (Sept. 1870 to end of war.)

COMPOSITION AND STRENGTH OF A SIEGE TRAIN

REQUIRED FOR

THE ATTACK OF A MODERN FORTRESS.

The R.A. Institution Prize Essay of 1877,

BY MAJOR W. KEMMIS, R.A.

"L'Artillerie est tout dans les siéges et presque tout dans la guerre de compagne."—*Montalembert.*

UNDER the head, "Siege Train," are included men, horses, carriages, ammunition and stores; in fact all personnel and matériel necessary, so far as artillery is concerned, for undertaking and prosecuting a siege. It is our province to treat of the matériel, in doing which it is convenient to consider each component by itself, commencing with the ordnance, as that lies, so to speak, at the base of all, and its nature and number being fixed determine in a great measure the remainder.

I. ORDNANCE.

Though it is very certain that, due to the increased effect of ordnance in range and destructive capacity, the method of siege hitherto in force is no longer, in the present day, applicable, yet the rôle of the artillery of the siege train, in an attack made en règle, remains as before, namely: primarily, to disable the armament, to render the terrepleins uninhabitable, to destroy the defences and to open a breach; secondarily, to assist in driving back the enemy within his works, in repulsing sorties, and in making good lodgements on captured works.

The necessity of disabling the armament, or, in other words, of subduing the fire of the defence, is the main point to be kept in view; Sir J. Jones, in his Note on the Siege of San Sebastian, thus insists upon it: *"To silence the fire of the place is the principal aim of all operations of a regular siege and is the spirit of the mode of attack adopted by Vauban. In a regular attack, where every point is gained inch by inch, it is impossible to succeed without overpowering the defensive artillery.—It is useless to attempt to sap near a place till its artillery fire is subdued." And this was proved at the Siege of Sebastopol, as General Niel, speaking of the construction of the sixth parallel on the glacis of the Malakoff bastion, tells us, †"The work of one night was generally but the re-establishment of that of the preceding—we must be content to wait the finishing of the parallel

* Note 32 Journal of Sieges in Spain, by Sir J. Jones.
† Siége de Sevastapol, par Le General Niel.

until our new batteries have deadened the fire of the artillery of the curtain," to which may be added, that, from the time the latter batteries opened the artillery of the attack was superior to that of the defence and the work proceeded.

If then, as these remarks shew, in the days of S.B. ordnance, it was obligatory on the besieger to subdue the fire of the besieged, how much more is it so now in the days of rifled ordnance, which are of far greater destructive power, while the means of protection, on the side of the besieger against that fire, remains but about the same as formerly. Brialmont, with reference to this, truly remarks, *"The zone in which the artillery of the defence can acquire a marked preponderance over that of the attack is much extended since the invention of rifled guns and the employment of the electric light."

But in order to subdue the fire of the defence the besieger must establish a superiority of fire, as Kraft points out when he says, speaking of the first batteries of the attack, †"That their number should be so regulated that a superiority of fire may be established over the enemy from the very first."

We may therefore say, that, in general,‡ for the attack of a fortress the besieger must have sufficient ordnance for:

Obtaining superiority over the fire of the place.
Effecting breaches.
Assisting in driving the enemy within his works, in repelling sorties and in effecting lodgements on captured works.

Such being the requirements of the attack, when we consider that the numbers necessary for the two last named purposes can be but small as compared to the first, it is evident that the actual ordnance required for the siege of any fortress must mainly depend, as regards a minimum, upon the ordnance mounted in that fortress, and in particular upon that front against which the attack is directed, as well as upon the disposition of the works themselves, not only of the front attacked but of the collateral fronts.

In fact—the calibres being given—"The exact number of pieces of ordnance required for the reduction of a fortress can only be correctly ascertained by the joint labours of the heads of the Artillery and Engineer service, after the plan of attack has been decided upon."‖

Though the case stands thus, it is however necessary to have a definitely organized siege train in readiness in the event of war,§ so that, as soon as war breaks out and a siege has to be undertaken, the train can be set in motion without waiting for details to be determined;

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* Brialmont, Traité de Fortification Polygonale.

† On Sieges, by Kraft, Prince of Hohenlohe-Ingelfingen, Major-General, Inspector of the 11th Artillery (Prussian) Inspection.

‡ "All general rules must occasionally be deviated from, genius will sometimes supply the place of numbers and necessity oblige where calculation condemns." Note 28, Journal of Sieges, by Sir J. Jones.

‖ Note 29, Journal of Sieges in Spain, by Sir J. Jones.

§ Si vis pacem, para bellum.

any particular supplement required, consequent upon the determination of details, being afterwards made out and sent to complete the train without confusion or trouble.

The strength and composition of a siege train, as regards ordnance, has been arrived at in various ways. Some, basing their estimate upon the classes into which fortresses have been divided, have fixed the train at the maximum necessary for the reduction of a first class fortress, leaving the number to be reduced for any other class; others have estimated it at so much per front, which amounts to much the same as the preceding mode; while others again have preferred to fix a unit which can be multiplied, as requisite, for any particular fortress.

The latter method is a convenient arrangement for peace administration, and in war furnishes a means of readily making up the numbers of the train to any extent; but it is necessary that the numbers and composition of the unit be based upon those of the total train required for a particular class of fortress, or the whole will be faulty.

It appears, therefore, that the only true way of arriving at the strength and composition of the siege train for the attack of a modern fortress is to take what may be regarded as a typical fortress and estimate the train most suitable for its reduction under modern conditions, checking the results obtained, so far as may be, by known facts and finally, for convenience of administration, fixing a unit.

As a typical fortress we must select one on the polygonal trace, "which assures to the artillery an action more direct and effective over the ground of attack than the bastioned trace, which has lost its importance in the manner in which artillery has progressed, so that, to-day it is condemned to the second place with S.B. guns and M.L. small arms,"* and it seems preferable to choose one of small size of the first class;† in which view we cannot take better than that described by Colonel Brialmont, in his "Traité de Fortification Polygonale," constructed upon a regular decagon, with side of 360m. (393 yards.)‡

On the investment of a fortress, previous to the arrival of a siege train, the besieger cannot maintain himself within the most effective ranges of the fortress, because of the loss and exertion which it would entail and because his field artillery would not have sufficient ammunition to keep up a constant fire day and night; hence, unless the defender has lost all energy, the besieger remains in such a position that the main body of his out-posts are not exposed to the fire of the artillery of the fortress.||

Under modern conditions, "it may be assumed, therefore, that the defender finally succeeds in pushing forward his out-posts to a distance of from 1000 to 2000 paces beyond the fortress, whilst the besieger's line of out-posts can seldom hold its position within 3000 paces and as

* Brialmont, Traité de Fortification Polygonale.

† The German fortresses have by a recent decision, been classified, as:—I., fortresses with first-class armament, as Strasburg, Posen, &c.; II., fortresses with second-class armament, as, Bitche, Thionville, &c.; III., works for coast defences, as Memel, &c.—Revue d'Artillerie, February, 1877.

‡ "The trace of Antwerp (*i.e.* polygonal of 1000 m. side), retains all its peculiar qualities when applied to fronts of 300 to 400 m."—Brialmont, Traité de Fortification Polygonale.

|| See, "On Sieges," by Kraft, Prince of Hohenlohe-Ingelfingen.

a rule is even further distant. In short the besieger eventually remains at a distance of from 2500 to 4000 paces," and "consequently the distance of the first batteries from the works will vary between these distances, according to the ground."*

In confirmation of this we find that the experience of the Franco-German war of 1870, proved "that the ranges of the batteries in the first artillery position, or for purposes purely of bombardment, kept, almost without exception, near the extreme limit then laid down, *i.e.* 3750m. (4101 yards.) This range was reached much oftener than was expected. In many instances it was even desirable or necessary to exceed this distance."† Since the war an increase in this limit has been aimed at and now the extreme ranges laid down for the different guns of the German siege train vary from 3800m. (4156 yards) to 8500m. (9295 yards) the average being about 5000m. (5468 yards.)

But "a second artillery position is necessary as the first is too far off to guarantee that certainty of hitting necessary for the absolute annihilation of the defensive powers of the besieged" and "the distance at which this should be placed will be somewhat less than half the distance of the first; but as its position will depend a great deal upon the ground, no definite numbers can be laid down."* And we find that, in the sieges during the Franco-German war of 1870, "the real fighting ranges, at which the artillery battle (dismounting and ricochet batteries) was successfully fought out, lay generally within the limits laid down viz: from 900 to 1200m. (984 to 1312 yards.) The latter showed itself to be the greatest admissible range for dismounting fire, although the wide French embrasures offering a mark that could be easily be hit, or destroyed, made it sometimes appear that a longer range could be used."† Endeavour has been made, since the war, to increase the above limits, as in the case of those for the artillery of the first position, by increasing the accuracy and power of the guns and at preseut 1500m. (1640 yards) is assumed as the limit in the case of the German 12 c.m. guns.

We have now to determine of what general description and nature of ordnance the siege train should consist; and this may, most conveniently, be done by considering the pieces for each position separately and afterwards putting them together, as a whole.

Descriptions and natures of ordnance for the first artillery position.—From this position the besieger should be able with his artillery fire to destroy all important buildings, as stores, depôts, &c., all interior defensive expedients, shelters, &c., and to prevent preparations for the defence by interrupting the arming, destroying the matériel and harassing communications, guards, working parties, &c; he should also be able to engage the fortress artillery with decisive results; while, further, he has to use his own artillery in driving the enemy back within his works and in repelling sorties when made.

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* On Sieges, by Kraft, Prince of Hohenlohe-Ingelfingen.

† Prussian Fortress and Siege Artillery, fourth part, by Major H. Müller.

Neglecting these last secondary requirements, clearly the primary, first mentioned, cannot be fulfilled at the same range, with maximum result, from the same description of ordnance, for while buildings, matériel and working parties, being covered by the works, can, for the most part, be reached only by high angle fire, the artillery upon the works may, more or less, be reached by direct fire.*

Again, it is wasteful and particularly objectionable, on account of the labor of transport, to use heavier ammunition than necessary for the attainment of a particular object.

Hence we are led to the conclusion, that the besieger must have the following ordnance for his first position, namely :

I. For bombardment:—(a) for destruction of buildings, (b) for destruction of matériel, (c) for destruction of men.
II. For fighting the enemy's artillery.
III. For driving back the enemy within his works.
IV. For repelling sorties.

From what has already been said as to the distance of the first position, we may, for the present, lay down 5468 yards (5000m.) as the minimum range for ordnance of nature (*a*), when laid at that elevation which gives the greatest range, or at about 45° ;† at this distance the accuracy should be fair, so that, when the position of the object fired at is exactly known, it may be reached without undue expenditure of ammunition. As the destructive power of the piece depends upon the penetration and effect on bursting of its projectile, the weight and capacity of the latter must be a maximum, limited only by the strength of the former; this in turn is governed by the weight admissible for transport, which should not exceed 65 cwt.‡

But there will be parts of the first position from which shelters may be reached by curved fire and so destroyed more readily than by high angle fire, which latter they might be sufficiently strong to resist,‖ therefore ordnance of nature (*a*) should be suited for this nature of fire,

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* Experiments have been carried out in Russia, 1875, at the suggestion of General Todleben, to ascertain the effect of placing the pieces of the defence some distance in rear of, instead of upon, the rampart, the results of which, however, appear inconclusive.—Revue d'Artillerie, January, 1877. Even if so placed, the pieces would be reached from the first position by direct fire.

† When practicable, the penetration will naturally be increased by reducing the range and giving greater elevation.

‡ See p. 109. Under difficulties of transport greater than ordinary, a lighter weight is desirable; for such exceptional purpose similar pieces of 55 cwts. might be used. See page 109, note.

‖ It is not to be expected that projectiles from the most powerful piece of this nature, which the besieger can place in position, will, with high angle fire, be effective against bomb proofs, for as the power of the besiegers ordnance is increased, so will the strength of the roofing be made to meet it. The results of German experiments and of the war of 1870, demonstrated the inefficiency of the 21 c.m. rifled mortar, against the usual arched covering, and against blockhouses with roofs formed of double beams 9·19 ft in thickness, covered with a layer of concrete 2·08 ft. thick, and earth 3·08 ft ; during the siege of Paris, strong casemate arches, 29·5 in. thick, with an earthern covering of 31·5in., were never penetrated by any projectile. (See Prussian Fortress and Siege Artillery, fourth part by Major H. Müller). At the Eastbourne experiments, 1874, shell from the 8 in. M.L.R. Howitzer failed to break through the roof of a splinter proof formed of

as well as for purely bombarding. In order to do this, with maximum effect, they must be capable of firing, at low angles of elevation, with considerable force of impact and accuracy and this can be obtained,* without impairing the power at high angles, by giving the piece greater length than necessary if used for the latter purpose only, and supplying it with a projectile of less weight†, than that already fixed at a maximum for bombardment, and which may be fired with a larger charge.

For destruction of matériel, a projectile of but medium weight and capacity is necessary, therefore ordnance of nature (*b*) may be considerably lighter than those of (*a*) and thus can more easily be brought into battery. Hence this nature may be employed in more advanced parts of the position than (*a*) and therefore its minimum range, at 45° of elevation, reduced to 4921 yards (4500m.); it may with advantage be as heavy as moderate ease of transport allows, namely, 37½ cwt.‡, and for for this weight should throw as powerful a shell as possible, with reasonable accuracy, it must also like (*a*) be available for curved fire,‖ and can be made so in a similar manner.†

Ordnance of nature (*c*) being for use in the most advanced parts of the first position, it does not appear necessary that its range should exceed 3827 yards (3500m.) as a minimum, and as the projectiles should not penetrate into the ground, the latter should be of minimum weight but with sufficient size and capacity for burster to break up into a considerable number of fragments. The work of this nature of piece necessitating frequently a rapid change of position its weight should not exceed 150lbs.¶

In ordnance of Description II, for fighting the enemy's artillery, range, accuracy and hard hitting are the desiderata, all which should be a maximum, limited only by the weight of piece admissible for transport namely, 75 cwt.** This nature of piece would be available for enfilade fire at long ranges, that is beyond the effective ranges of (*a*) or (*b*) and

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36 lb. rails, when covered with 6ft. of earth; and, in the experiments of 1876, a 10 in. M.L.R. shell, falling at an angle of 45°, on the concrete roof of a casemate produced but little effect. "The destruction of such works (arches covered with earth) should, if possible, in future be effected by means of indirect fire."—Prussian Field and Siege Artillery, fourth part, by Major H. Müller.

* In Germany, from the experience of the war of 1870, experiments have been carried out in view of superseding the 21 c.m. rifled mortar by a short gun of the same calibre—a combination of mortar and howitzer—the mortar having failed, as already mentioned, to destroy bomb proofs by vertical fire and the short 15 c.m. gun not always sufficing to do it by indirect fire.

"It may be hinted, that, when we succeed in constructing a short 21 c.m. gun, the effect from our first artillery position will be considerably increased."—Kraft, on Sieges.

† This piece would thus have two shells of different weight.

‡ See p. 109.

‖ To reach a gun, immediately behind a casemated traverse, an angle of descent of about 25° is required.

"At longer ranges of 1200 to 3000 m. (1312 to 3281 yds.) the mortar-like effect of the 15 c.m. gun can, in such cases, (enfilade firing), be utilised. The guns fire thus at an angle of 25° to 30°, with a charge corresponding to the distance."—Curved fire, by Count Bylandt-Rheidt, Major General in the Austrian Service.

¶ See p. 110.

** See p. 109. Under difficulties of transport, greater than usual, similar pieces of 55 cwt. might be used; see p. 109, note.

for bombardment at exceptional ranges, that is, beyond the extreme ranges of the same.*

For driving back the enemy (III.) it is unnecessary that there should be a special piece provided; one of considerable range, power and accuracy is desirable, and, therefore, the medium gun of the second position, (see after) not required for its normal work at the early period of the siege, is best suited.

In a similar manner it is unnecessary to provide a special description of piece for assisting in the repulse of sorties (IV.) In this case less range and power is required than in the previous; the heavier field gun is therefore sufficient, but in conjunction with it the mitrailleuse might with advantage be employed, especially "Wherever the enemy is obliged to select definite lines of advance within its effective range."†

The artillery of the first position should therefore consist of:—

I. *Heavy rifled Howitzers.*
Medium „ „
Light „ „
II. *Heavy rifled guns.*
Medium „ „
III. *Field guns and mitrailleuses.*

DESCRIPTIONS AND NATURES OF ORDNANCE FOR THE SECOND ARTILLERY POSITION.—From this position the besieger has to complete the work commenced in the first, more particularly that of fighting the enemy's artillery. He has also to effect demolitions and breaches, to keep under the infantry fire where annoying, and to make lodgements on captured works. He therefore requires the following ordnance:—

I. *For fighting the enemy's artillery.*
II. *For effecting breaches and demolitions.*
III. *For keeping under infantry fire.*
IV. *For making lodgements.*

For fighting the enemy's artillery (I.) a less powerful piece is required in the second than in the first position on account of the less distance of the former from the fortress. From what has already been said, it appears desirable that the piece should be effective for dismounting‡

* It is stated that the German 15 c.m. ring gun can be used for enfilade fire with effect up to 5000 m., (5468 yds.) while its extreme range is 8500 m. (9295 yds.)

† On Sieges, by Kraft, Prince of Hohenlohe-Ingelfingen.

"The mitrailleuse exercises a great influence over the soldier; the same man would recoil from a mitrailleuse who would brave, without wincing, the fire of 20 riflemen."—Brialmont.

‡ The German 12 c.m. gun, "the most useful one for dismounting fire," is considered to be effective for that purpose at 1500 m. (1640 yds.) and the short 15 c.m. gun at 1200 m. (1312 yds.)

In Russia, experiments have been made with the view of ascertaining the effect of the fire of the attack to dismount guns placed in different positions in a fortress; the siege battery was situated at 1167 yds. from the rampart of the place, and armed with two guns of 24, throwing projectiles of 64·9 lbs. From these it took 26 rounds to dismount a gun on the rampart en barbette; 10, one on the rampart behind a deep embrasure; 52, one on the rampart behind a shallow embrasure and withdrawn to the rear of the terreplein; 75, one mounted in the covered way, and 40, one placed in battery in the interior of the bastion, 98 yds. from the rampart.—Revue d'Artillery, January, 1877.

at a range of 1600 yards, as a minimum; it should fulfil the same general conditions as the corresponding gun of the first position, its power being a maximum for that weight which moderate ease of draught allows, namely, 37½ cwts.*, for, as the besieger approaches the fortress and gets further from his park, the difficulties of bringing guns into battery increase.

Where enfilade fire, for dismounting, is possible, which will be the exception, it can be continued by the pieces of the first position, allotted to that purpose, moved into the second position, if necessary, to complete their work, and therefore there is no need to make special provision for this purpose in the latter position.

With regard to Description II. we may assume that breaches will, as a rule, in future be made from a distance by curved fire,† the besieger not only thus avoiding much difficulty of transport and the execution of "crowning" works, but because "they demoralise the garrison, facilitate attack *de vive force*, augment the difficulties of guarding and enfeeble the action of the artillery in this way, that the besieged loses or must retire the pieces which are behind the falling parapet."‡

The practicability of this manner of breaching, under certain conditions has been demonstrated at the siege of Strasburg in the Franco-German war of 1870, and by experiments since carried out in Germany;‖ but the profile and width of ditch in modern fortresses will render the conditions usually much more unfavourable than in the instances quoted, necessitating an angle of fall of about 26° to reach the middle of the escarp (see Plate I. fig. 1) which, with the final velocity necessary for breaching, will be difficult to obtain. We cannot, however, even under the most unfavourable conditions, consider breaching by

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If guns in the future are mounted in the last-mentioned manner, they would have to be reached from the second position by curved fire, in which case medium howitzers would take the place of medium guns for the purpose.

In England there have been no experiments in dismounting fire to the results of which we can refer.

* See p. 109.

† "We take it for granted that, as a rule, crowning batteries are unnecessary, and that curved fire, corrected, if necessary, by observation, from the crowning, will do all that is required."—Kraft, on Sieges.

‡ La fortification déduite de son histoire, par le General Tripier.

‖ At Strasburg, in breaching the right face of Lunette 53, with the 15 c.m. short gun, the range was 853 yds., the angle of descent 7° 7½′ and the angle of fire with the wall 55°; the latter being of red sandstone about 4½′ thick at top and 6¼′ at bottom.

At the experiments of Graudenz, 1873, the 12 c.m. gun rendered a capioner of brick quite untenable, the walls of which were 4¼′ thick at the upper storey and 5¼′ at the lower, from a range of 1487 yds. In a wall of granite boulders, of considerable size, and 16·4′ in thickness at the top, including buttresses, the short 15 c.m. gun made a practicable breach at a range of 1148 yds., with angle of descent 7°, and horizontal angle of impact 57½°; and the short 21 c.m. gun at a range of 1170 yds., with angle of descent of 6° 37½′, and horizontal angle of impact about 57½°. From the results of these experiments it is stated that, "the practicability of demolition at angles of descent up to 15° may be accepted," and "that generally the conditions should be so arranged as to secure 25 to 30 per cent. of masonry hits, with a final velocity of 525 to 591 feet."—Prussian Fortress and Siege Artillery, fourth part, by Major H. Müller.—We may remark that these conclusions only hold good for the particular guns then under trial, for the limiting angle of descent to effect a given demolition, without undue expenditure of ammunition, varies with the accuracy of the gun used and its power. No experiments have been made in England on this point to the results of which we can refer.

curved fire impossible,* nor yet even more difficult than by direct fire from the crowning; for, if the requisite final velocity cannot be obtained by increasing the range† to the effective limit, it may be by diminishing the required angle of descent, either by firing at the covering work or by mining it;‡ a labour which would equally have to be gone through in the case of direct fire from the crowning. (See Plate I. fig. 1.)

Curved fire being, therefore, employed in breaching and in similar work, such as the demolition of casemated flanking works, the ordnance employed in the first artillery position|| for this nature of fire are equally suited for it in the second; it becomes merely a question whether the heavy or the light nature is best for the purpose. To throw light upon this we may refer to the experience of the Franco-German war of 1870, that, "the short 15 c.m. gun had taken four firing days (about 48 hours) of indirect fire for the establishment of a breach at Strasburg; a length of time which, in many cases, would have to be curtailed, and which only could be done by the employment of a larger calibre." And, again, to the results of the Graudenz experiments, that "a comparison of the effect of the short 15 c.m. and 21 c.m. gun§ shews, that, with the same striking velocity, an equal weight of projectiles was required to produce equal results. The advantage of the heavy calibre is not therefore to be sought in the use of less ammunition, but in other factors; these are time and accuracy. A reduction in time for breaching will always be important and necessary, if only with reference to the suitable combination of this mode of firing with the works of the engineers."** To this we may add that, for a given high angle of descent, the requisite final velocity will more readily be obtained from the heavier than from the lighter nature, for the former will perform the same work as the latter with a much less final velocity, even allowing for the greater resistance of the masonry due

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* If, however, in works of the future, the escarp or work to be demolished is protected by armour plates, direct fire must be employed to pierce and loosen them, and the besiegers will have to place in battery, by mechanical means, pieces of far heavier nature than now in use.

† Nothing is gained in reducing the angle of descent by making the line of fire oblique, for example; the Austrian short 15 c.m. gun, at a range of 1640 yds. with charge of 1·54 lbs., at an angle of descent of 22° 7′, has a final normal energy of 172,200 ft. lbs., but, if the angle of descent be reduced to 15° 55′ by making the line of fire 46° oblique, at the same range, with charge of 1·98 lbs. the final normal energy is only 118,600 ft. lbs. If, however the angle of descent be kept at 22° 7′, and the range increased to 2170 yds. with charge of 1·98 lbs. the final normal energy will be 216,000 ft. lbs.

With high angles of descent the point of impact may possibly be taken higher than the middle of the escarp, and the requisite angle so reduced; for, the higher the angle, the greater the tendency to cut downwards as well as into the masonry.

‡ This no doubt will, in future, be generally necessary, unless pieces of far greater power than now in use are introduced into the siege train for breaching and perhaps even then. Possibly simple horizontal boring might take the place of mining.

|| That is for enfilade chiefly.

§ The 15 c.m. short gun expended 74·5 shots (about 61·1 lbs. the projectile) per metre of breach, the 21 c.m. gun 30·4 shots (about 176·0 lbs. the projectile.)

** Prussian Fortress and Siege Artillery, fourth part, by Major H. Müller.

to the greater calibre,* and this again admits of the easier attainment of any required angle of descent.

We are therefore led to the conclusion that the heavier piece is the best for breaching and such like purposes; at the same time the lighter will frequently be sufficient, especially for the demolition of casemated works.

Similar conditions have to be fulfilled in keeping under infantry fire (III.) as in harassing working parties, therefore the piece, which serves for the latter in the first position, will serve for the former in the second.

For effecting lodgements on captured works (IV.) a light and effective piece being required the heavier field gun will in ordinary† be sufficient.

We thus conclude that for the artillery of the second position there are required:—

I. *Heavy rifled howitzers.*
Medium „ „
Light „ „
II. *Medium rifled guns.*
III. *Field guns.*

Recapitulating we have therefore, the—

DESCRIPTIONS AND NATURES OF ORDNANCE REQUIRED FOR THE SIEGE TRAIN, as—

I. *Heavy rifled howitzers.*
§*Medium* „ „
Light „ „
II. §*Heavy rifled guns.*
Medium „ „
III. *Field guns and mitrailleuses.*

Of these, in the British Service, the heavy or medium howitzers have no representative,‡ and corresponding to the remaining pieces are, the 7 pr. M.L.R.; 64 pr. M.L.R.; 40 pr. M.L.R. and 25 pr. M.L.R.; 16 pr. M.L.R. and ·45Gatling.

In the German Service, the heavy|| and light howitzers have no representative and corresponding to the remainder are, the 15 c.m. B.L.R short gun; 15 c.m. B.L.R. long gun; 12 c.m. B.L.R. gun; 9 c.m. B.L.R. gun and the mitrailleuse.

We have next to calculate the number of pieces of each nature required; where the frontal attack is employed, which will be the rule, in dismounting fire gun for gun of the defence must be allowed as "one gun in the former (*i.e.* the atttack) will only be worth as much as one

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* Thus assuming the final normal velocity, necessary for breaching effectively, to be 524·9 ft. (160 m.) with the short 15 c.m. gun; with the 21 c.m. gun to do the same work, it need only be 374·7 ft. (114·1 m.)

† For special cases, in lodgements for breaching, &c., the medium gun or howitzer can be used.

§ These may conveniently be of the same calibre.

‡ The 8 in. and 6·3 in. M.L.R. howitzers hardly represent howitzers proper; they are more of the nature of mortars.

|| As already mentioned, experiments have been made in Germany with a 21 c.m. short gun.

in the latter,"* but where it is possible to employ enfilade† fire for dismounting a less number may be allowed, the opportunity for this however will seldom be presented in modern fortifications and those lines open to it will be well traversed.

Plate I. fig. 3 shews the general outline of a front of the fortress selected as type, the batteries of which are, as follows :—

The Ravelin, A. consists of a casemated battery *de reverse a*, mounting 7 guns,‡ 3 on each flank and 1 on the capital; of two faces *b.b.* of 2 guns each, with a mortar battery between them; of two flanks *c.c.* of 5 guns each, and of two low casemated flanking batteries *d.d.* of 4 guns each.

The Caponier B. mounts on each flank 4 guns|| in casemates and 3 in battery *ouverte à ciel*.§

The Curtain C.¶ has two batteries *e.e.* flanking the caponier, of 4 guns each in casemates and 3 in battery *ouverte à ciel*; two flanks *f.f.* of 3 guns each and between the flanks space for 6 guns, *ouverte à ciel*.

On each of the faces D.D. of the Body of the place (including the salient) there is space for 8 guns.

In addition to the mortar battery in the Ravelin there will be batteries for heavy mortars in the body of the place and for light in the re-entering places of arms, &c.

In the salients of the Covered way there will be blockhouses of timber or masonry, the front of each protected by a mask of earth.

We may assume the guns mounted on the works to be of 15 c.m. calibre, except in the flanking batteries *d.d.*, *f.f.* and casemates *e.e.* which may have 12 c.m. calibre and the salients of the encient, which may have 21 c.m. or even heavier guns. The total armament of a front (without mortars) including all the flanking batteries is therefore, on the above supositions, 1 gun of 21 c.m.; 61 of 15 c.m.; 22 of 12 c.m. = 84 pieces.

In estimating the requirements of the besieger, as to numbers, to meet this armament, it is convenient, as before in ascertaining the descriptions and natures, to consider each position independently, in the first instance.

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* Prussian Fortress and Siege Artillery, fourth part, by Major H. Müller.

† It is hardly necessary to say that we regard enfilade fire *a ricochet* as impossible from rifled guns.

‡ "Five pieces at least, seven at most.—It will be necessary to protect by armour plates the piece firing on the capital, this piece having to enter into action from the commencement of the siege, and being open to be counter-battered from far.—If the front is one of great importance a revolving cupola should be established at the salient of the ravelin to batter the works of the attack by direct, enfilade and reverse fire, in a field of fire of about 260°. This cupola would replace with advantage the armoured piece of the salient and casemated battery *de reverse*."—Brialmont. When armoured pieces and cupolas are introduced for land defences, as already mentioned, the besieger will be obliged to place in battery, by mechanical means, pieces of far greater power than now in use.

|| "The alternate casemates are reserved for the lodgement of men, if they were also opened, more guns could be mounted."—Brialmont.

§ "If it was desired to increase the power of the caponier, one might construct, on its platform, a casemated battery, à la Haxo."—Brialmont.

¶ The curtain has 4½ m. command over the caponier and 5 m. over the ravelin, and therefore its fire can act simultaneously with that of the latter work.

NUMBER OF ORDNANCE REQUIRED FOR THE FIRST ARTILLERY POSITION, FOR ONE FRONT.—To fight the salient gun and those of the faces of the Ravelin 5 guns are necessary, and these, serving also in some measures to enfilade the battery of the caponier, *ouverte à ciel*, and to counter batter the guns of the curtain, may well have another added to their number making a total of 6; they would be established, as nearly as may be, on the prolongation of the capital and associated with them, for bombarding, there may be 4 heavy and 2 medium howitzers.

The flanks of the Ravelin may be enfiladed,* but are each protected by the battery *de reverse* at the salient as by a casemated traverse,† as well as by casemated and splinter proof traverses; for this purpose 3 medium and 1 heavy howitzers must, at the least, be allowed per flank, adjacent to which, for dismounting the low battery flanking the ravelin and destroying the traverses of the covered way, may be placed 4 medium howitzers.

The faces of the body of the place cannot be enfiladed‡ their prolongations falling upon the Ravelins of the contiguous fronts; for fighting the guns of each, 5 guns may be allowed, in the first position and with them, for bombardment, may be placed 4 heavy and 2 medium howitzers.

To meet the heavy gun of the salient of the body of the place 2 guns are necessary and with them, on the prolongation of the capital, as nearly as may be, may be placed 6 heavy howitzers for bombardment.

Adding|| to the preceding numbers 12 light howitzers for use against working parties, &c., and 12 field guns and mitrailleuses for emplacements against sorties, we get as the total ordnance necessary for the first position :—

Guns :—	*heavy*, 18.	*medium*, —	*field*§ 12.
Howitzers :—	*heavy*, 20.	*medium*, 20.	*light*, 12.

NUMBER OF ORDNANCE REQUIRED FOR THE SECOND ARTILLERY POSITION, FOR ONE FRONT.—In the fortress are mounted, as we have seen, upon the faces and curtain of the encient 26 guns (neglecting the one in the salient) having a large field of fire; for counter-battering these, but 10 have been allowed in the first position, there remain therefore 16 to be provided¶ and as these will probably be of lighter calibre (about 4·7″) than those of the fortress (supposed 15 c.m. = 5·9″) their number must be increased by at least 25 per cent. or to 20.

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* Though, truly, as Brialmont states, "Le ravelin offre peu de prise au tir d'enfilade."

† The angle of fall required to reach the guns mounted next to the battery *de reverse* is about 15°, that to reach a gun next a casemated traverse about 25°.

‡ "That enfilade fire be effective one must be able to judge the effect of the rounds and rectify the laying, which cannot be when enfilading a line of which the prolongation is out of sight."—Brialmont.

|| As already stated, guns of the second position can be used for driving back the enemy, and, therefore, it is unnecessary to provide specially for this purpose in the first position.

§ Field guns and mitrailleuses.

¶ Any effect produced on these works by the pieces placed in battery against the Ravelin, in the first position and continued in the second, is neglected in order to ensure superiority on the part of the besieger.

For the demolition of one flank of the battery *de reverse*, 3 medium howitzers are required* and for one flank of the caponier, at least 4 heavy and 2 medium howitzers.

For the reduction of the casemated guns flanking the caponier 6 medium howitzers are necessary, but as these pieces will not be required until a late period of the siege they may be provided from those of the first position. In like manner it seems unnecessary to provide especially for the reduction of the guns flanking the terreplein of the caponier.†

For breaching the flank of the Ravelin 4 medium howitzers will be sufficient, while for the face of the encient 6 heavy howitzers must be allowed.‡

For keeping under the infantry fire of the covered ways, &c., 6 light howitzers may be added to those of the first position and for effecting lodgements on captured works the field guns allowed for emplacements, and no longer required for that purpose, will serve.

Thus, in addition to the ordnance of the first position, there are required for the second.—

Guns:—	*heavy*, —	*medium*, 20.	*field*, —
Howitzers:—	*heavy*, 10.	*medium*, 9.	*light*, 6.

Therefore.

THE TOTAL ORDNANCE REQUIRED FOR THE ATTACK OPPOSITE ONE FRONT, is.—

Guns:—	*heavy*, 18.	*medium*, 20.	*field*‖ 12.
Howitzers:—	*heavy*, 30.	*medium*, 30.§	*light*, 18.

in all 128 pieces, of which 64 may be considered as allotted for subduing the fire of the front, the remainder being for bombardment and special purposes.

If now we suppose the attack made on salient III. Plate II., there are required opposite the fronts II.-III., III.-IV., double the above number and in addition 6 heavy howitzers and 2 heavy guns for the battery on the prolongation of the third capital, or :—

THE TOTAL ORDNANCE REQUIRED FOR THE ATTACK OPPOSITE TWO FRONTS, is.—

Guns:—	*heavy*, 38.	*medium*, 40.	*field*‖ 24.
Howitzers:—	*heavy*, 66.	*medium*, 60.	*light*, 36.

or 264 pieces.

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* These will also complete the dismounting of any guns on the flank of the ravelin, unsubdued by the enfilade fire.

† If the besieger does not enter the fortress by the caponier, the reduction of these is not necessary.

‡ As already stated, heavy howitzers are better for breaching than medium, but, the former being provided for breaching the encient, they can supplement the medium allowed for breaching the ravelin, or even, should circumstances permit, take their place altogether, thus first breaching the ravelin and then the encient. Again, we may assume the revetment of the former work to be of less strength than of the latter.

At the siege of Strasburg, the Germans employed four short 15 c.m. guns on two occasions to form breaches and six on a third.

‖ Field Guns and mitrailleuses.

§ One added to make the number even.

We find on reference to Plate II. that even, if the guns of the fortress have but 60° field of fire, it will permit nearly all those of the high batteries of the body of the place, together with the salient gun and some of those on the faces of the Ravelin, on front IV.-V. to bear on a siege battery established for the demolition of the caponier of front III.-IV. through that battery be approached to 1214 yards (1110m.) ; also the guns of the upper tier of the caponier and those of the flank and of the battery *de reverse* of the Ravelin, of front IV.-V. bear upon the ground of attack. In order to keep under the fire of the former 8 heavy and 10 medium guns, and 8 heavy and 4 medium howitzers will, at the least, be required and for the latter 8 medium howitzers. In addition to these 4 heavy howitzers may be allowed for the upper tier of the caponier and for the battery *de reverse* of the front still more remote from the salient attacked, which also bear upon the besieger's approaches. Adding the same number of pieces for the collateral works bearing on the right attack and taking the sum of all, we find they approximate very nearly to the numbers for the attack of one front, less pieces for breaching and other special purposes, (namely, 18 heavy and 20 medium guns, 24 heavy aud 26 medium howitzers.) It seems therefore desirable to substitute the latter and so have but one proportion that founded upon the main requirements, as the basis, so to speak, of the siege train. This gives :—

THE TOTAL ORDNANCE REQUIRED FOR THE SIEGE TRAIN, as :—

Guns :—	*heavy*, 56.	*medium*, 60.	*field** 24.
Howitzers :—	*heavy*, 90.	*medium*, 86.	*light*, 36.

or 352 pieces,† to which must be added 10 per cent. to allow for guns dismounted, under repair, &c. This gives a grand total of :

Guns :—	*heavy*, 62.	*medium*, 66.	*field** 26.
Howitzers :—	*heavy*, 100.	*medium*, 94.	*light*, 40.

or 388 pieces, as the minimum number‡ required for the siege of the fortress.

THE PERCENTAGE OF THE TRAIN, is therefore :—

Guns :—	*heavy*, 16.	*medium*, 17.	*field** 7.
Howitzers :—	*heavy*, 26.	*medium*, 24.	*light*, 10.

The British siege train is laid down to consist of any number of units, composed of heavy or light ordnance, according to the requirements of the Service. Taking the heavy unit,§ we find it to consist of eight 64

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* Field guns and mitrailleuses.

† The men required to serve this number, at two reliefs, (which is hardly sufficient for continuous work), with 25 p.c. to cover casualties, would be 8,320 or 55 Batteries of Artillery, each 152 strong in rank and file.

‡ "The maximum number must be limited to those which can be employed at one time, with an addition of 10 to 20 p. c. as a reserve."—Kraft, on Sieges.

§ The light unit consists of ten 40 pr. M.L.R. guns, ten 25 pr. M.L.R. guns and ten 6·3 in. M.L.R. howitzers with six 7 pr. M.L.R. guns.

The heavy and light units might be combined in the same train, but it would be difficult to arrive at a satisfactory percentage by any such combination.

pr. M.L.R. guns, eight 40 pr. M.L.R. guns, fourteen 8 in. M.L.R. howitzers with six 7 pr. M.L.R. guns which gives a percentage, to compare with the above, of;

Guns :—	*heavy*, 22.	*medium*, 22.	*field*, —
Howitzers :—	*heavy*,*—	*medium*, —	*light*, 17.
Mortars :—	*heavy*, 39.		

The experience of the war of 1870 showed that the German† siege train should be considerably increased and, consequently, it was recommended that it should be made to consist of 400 pieces, of which 360 to be rifled ;‡ of these the 12 c.m. guns to form 38 p.c. and the short 15 c.m. guns 45 p.c.

If now, for convenience of organization in time of peace, a unit is to be fixed for the siege train, clearly it can only be the 100 pieces formed by the percentage numbers of the total train, (or a less number given by the same submultiple of those numbers), or, instead of one, two distinct units formed by the percentage numbers of each position. In the attack the piece itself must become the unit, or, in each nature, that number of pieces, which a Battery of artillery can furnish men to work.

The number of pieces for the attack of a front of any similar fortress to that taken as typical, constructed upon a polygon of other length of side than 393 yards, (360 m.) may be estimated from the train for the typical fortress by simply making it proportional to the length of side and afterwards subdividing the number thus obtained into the proper percentage for each nature: from which, as basis, the total train required for the fortress is readily deduced. If the fortress estimated for be very strong and has great length of exterior side, there will be a

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* As already mentioned, the 8 in. howitzer is more of a mortar than a howitzer.

† A Russian train consists of 400 pieces divided into 12 sections, as follows.—1 and 2 form the *parc d'investissement* and consist each of 32 rifled 9 c.m. guns; 3 to 10 form the *parc de l'attaque*, 3 to 6 consisting each of 24 rifled 15 c.m. guns and 4 rifled 15 c.m. mortars, 7 to 10 of 16 rifled 15 c.m. guns, 8 rifled 21 c.m. 4 rifled 15 c.m. and 8 smooth-bore mortars; 11 and 12 constitute the *parc de reserve* consisting each of 20 rifled 15 c.m. and 8 rifled 9 c.m. guns, with 4 rifled 21 c.m. 4 rifled 15 c.m. and 4 smooth-bore mortars; (Of the 15 c.m. guns 60 are heavy and 140 light.) To the train is attached 6 Battaliions of Artillery, each of an effective strength of 1355, viz.:—21 officers, 100 N.C. officers 8 trumpeters, 1,200 gunners and 26 non-combatants."—Revue d'Artillerie, May, 1877.

‡ See Prussian Fortress and Siege Artillery, 4th part, by Major H. Müller.

For the siege of Strasburg 371 pieces were provided, the extent of front directly attacked being about 900 yds.

Kraft, in his pamphlet on sieges, recommends the relative proportions for a siege train, assuming S.B. mortars are not required, as :—

15 c.m. long guns	25 p.c.
„ short ...	25 „
12 c.m. guns ...	30 „
9 c.m. guns ...	10 „
21 c.m. mortars...	10 „

or, for comparison, with the estimated train,

Guns :—heavy, 25 p.c.	medium, 30 p.c.	field, 10 p.c.
Howitzers :—heavy —	medium, 25 p.c.	light ——
Mortars:—heavy 10 p.c.		

but, as already mentioned at the conclusion of his pamphlet, he hints at the desirability of introducing a heavy howitzer.

proportionately greater number of the heaviest guns mounted in it and there will be more frequent use of two tiers of fire, this will however be balanced in the number of pieces allowed for keeping down the fire of collateral works, which, from the greater distance of the works from the attack, will be less annoying. In this view, we find for the attack of a fortress constructed on a decagon of 1093 yards (1000m.)* side, there is required opposite one front 356 pieces, namely:—

Guns:—	*heavy*, 50.	*medium*, 55.	*field*, 33.
Howitzers:—	*heavy*, 84.	*medium*, 84.	*light*, 50.

and for the minimum total train,† without spare:—

Guns:—	*heavy*, 152.	*medium*, 165.	*field*, 66.
Howitzers:—	*heavy*, 252.	*medium*, 248.	*light*, 100.

II. AMMUNITION.

"In the earlier maxims upon sieges, a certain number of rounds was laid down for each gun, which had to suffice for the whole siege. This no longer holds good, for if the fortress does not yield after 800 or 1000 rounds per gun we must go on firing or else we are beaten off."‡ But though the total amount of ammunition for the reduction of any fortress must thus, as it were, be unlimited, it is necessary in peace, in order to readiness for war, to have a certain store of ammunition prepared with the ordnance of the siege train. This store should be such that, when supplied with the ordnance, for the attack of a fortress, there would be no chance of cessation of fire from any deficiency, "because a cessation of fire from want of ammunition enables the enemy to repair his damages and acts therefore as a great check;"‡ its actual amount must therefore depend upon the total probable amount required for the reduction of the fortress and upon the means and manner of renewing and keeping up the supply.§

Assuming the siege to last 30 days, that is; 3 days to the establishment of the first artillery position, 7 days from that to the establishment of the second and 20 days from the latter to the assault, the total amount of ammunition necessary for the train, namely, for 352 pieces, (the spare omitted), may be estimated as follows;—

Bombarding batteries continue open during the whole siege, allowing therefore for each of the heavy (66) and medium howitzers (40) of these 48 rounds¶ per day (of 24 hours) as an average for 27 days, and 36

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* This is about the length of front of the fortifications of Antwerp.

† "Paris would have required at least three entire Prussian siege trains, if we had wished to employ the formal attack for its capture."—Kraft on Sieges.

‡ Kraft, on Sieges.

§ "Measures must be taken for keeping up the home manufacture of matériel, so that there may be a continuous certain supply to replace expenditure."—Kraft, on Sieges.

¶ "A daily allowance of 50 to 60 rounds per gun gives a very brisk fire; more than this has generally not seemed desirable."—Kraft, on Sieges.

rounds per day for each light howitzer (24) for the 7 days of the first position, there is required for bombarding ;—

Double shell : —Heavy howitzer*, 85536. *Medium howitzer*, 51840.
Common shell :—*Light howitzer*, 6048.

Enfilading batteries fire at first to produce the utmost effect, afterwards keeping up only such regular fire, as is sufficient to prevent the besieged repairing his works or remounting his ordnance ; for this purpose, there may therefore be allowed, per piece, (4 heavy, 12 medium howitzers) for each of the first two days they are in action, 56 rounds, and afterwards, until the occupation of the Ravelin,† an average per day of 24 rounds. Of the latter, for the medium howitzers, $\frac{1}{4}$ may with advantage be shrapnel to sweep the terrepleins and keep them clear after the guns have been dismounted and the traverses ruined. In addition each howitzer must be provided with some case shot to meet sorties, in the event of their being so far successful as to approach the batteries ; this, however, will but seldom occur and therefore 12 rounds per piece will be sufficient for the contingency. We have thus the ammunition necessary for the enfilading batteries :—

Common shell :—*Heavy howitzer*,	2368.	*Medium howitzer*,	5664.
Shrapnell shell :—	,,	—	,,	1440.
Case shot :—	,,	48	,,	144.

Batteries for fighting the enemy's artillery continue open from their establishment to the assault, their fire being brisk at first and afterwards less as the enemy's guns become disabled; allowing, as an average, for each gun 48 rounds, per day, there is required, for this purpose 72576 rounds for heavy guns (56) and 57600 for medium guns (60). Of this a proportion must be shrapnel, for silencing the enemy's fire, temporarily, by driving the gun detachments from their guns, when it cannot at the time be done effectually otherwise and for other occasional use‡ ; also, some case must be added for use against successful sorties. For the purposes required, shrapnel in the proportion of $\frac{1}{20}$ the total number of rounds (exclusive of case) will give an ample supply, while 5 rounds of case per heavy gun‖ and 12 per medium gun will be sufficient.

But medium guns, being used in the first position for driving the enemy back, such of them as are so employed, require for the time, a further supply of 48 rounds, each per day ; of which quantity $\frac{3}{4}$, at least, should be shrapnel, while of case the supply already made for this nature

* The heavy and medium howitzers, as already stated, should have shells of two weights, one a maximum, which for distinction we term "double," and the other medium, or "common." Special incendiary projectiles seem unnecessary, the large bursters of shells sufficiently serving the purpose ; for extraordinary use a few rockets might be supplied.

† On the 25th day of the siege, we assume.

‡ Shrapnel in frontal fire cannot as effectually clear the terreplein as it can in enfilade fire, and therefore for preventing the remounting of ordnance, &c., apart from the effect on the matériel, is not then so useful as common shell.

‖ The heavy guns will seldom be open to attack from sorties and in any case will only be liable to it for a short period of time.

is sufficient. We may assume $\frac{2}{3}$ of the medium guns to be employed in this manner; the total amount of ammunition required for both natures of guns is then*;—

Common shell:—Heavy guns,	68948.	*Medium guns*,	58080.
†*Shrapnell shell:*—	,,	3628.	,,	12960.
Case shot:—	,,	280.	,,	720.

Breaching batteries fire as quickly as they can with precision during daylight and during night keep up only sufficient fire to prevent the beseiged doing anything towards the repair of the damage done. The amount of ammunition requisite for the pieces of these batteries is better based directly upon that quantity required to form a practicable breach, than indirectly upon the time it may occupy to do so. This quantity will necessarily vary not only with the nature of the revetment and the gun employed, but upon the circumstances of range, &c., under which the latter is used.

From the experience of the siege of Strasburg and from the results of the German experiments on breaching, already mentioned,‡ we may assume that per yard of breach, under favourable conditions|| for curved fire, heavy ordnance must expend 35 rounds and medium 80, to make the breach practicable. Adding 50 per cent. to these figures, as a margin to meet less favourable conditions, or those which, as already stated, will generally rule; and shrapnel, at the rate of 48 rounds per night (12 hours) for each heavy piece for two nights, and for each medium piece for three nights, with an addition of 50 per cent. for keeping the breach clear after completion until the assault; we get the following ammunition as necessary for the pieces (12 heavy, 8 medium howitzers) making breaches in the faces of the encient 33 yards wide and in the flanks of the ravelins 22 yards, namely:—

Common shell:—Heavy howitzer,	3464.	*Medium howitzers*,	5280.
Shrapnell shell:—	,,	1728.	,,	1728.

For demolition of casemated works a somewhat less proportion of ammunition than for breaching will suffice; allowing 35 rounds for heavy howitzers (8) and 80 for medium, (26) per yard, for $\frac{3}{4}$ of the length of the work to be demolished and 20 per cent. additional, gives us the ammunition required for this purpose to be:—

Common shell:—Heavy howitzer, 2520. *Medium howitzer*, 12960.

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* Should works of the future be armour plated, the heavy guns, employed then for breaching or demolition, will require special projectiles for the purpose.

† The proportion of shrapnel to common shell for the medium gun is thus 1 to 4·48 (in the heavy 1 to 19,) In the heavy unit of the English siege train the laid down proportion for the 64 pr. and 40 pr. is 1 to 2·26, this however seems large.

‡ Note p. 96 and note p. 97.

|| The masonry fired at in the Graudentz experiments was very strong but the angle of descent less than what in practice we may generally expect it to be.

To meet sorties both breaching and demolition batteries must be provided with case, at 10 rounds per piece this amounts to :—

Case shot :—Heavy Howitzer, 200. *Medium Howitzer*, 340.

For the light howitzers (36) of the 2nd position not yet provided for, an average of 30 rounds a day, per piece, will be sufficient, which gives :—

Common shell :—Light howitzer, 21600.

The field guns (24) only now remain to be estimated for; a less average than in the preceding, or 24 rounds a day, per piece, will suffice for these and we may consider them, in emplacements or lodgements, to be in action for half the duration of the siege.* This amount may be divided in the proportions of $\frac{1}{10}$ common shell, $\frac{7}{10}$ shrapnel, $\frac{2}{10}$ case. We have then :—

Common shell :—Field guns,		764.
†*Shrapnell shell* :—	,,	5348.
†*Case shot* :—	,,	1528.

Summing up we find :—

THE TOTAL PROBABLE AMOUNT OF AMMUNITION FOR THE TRAIN SHOULD CONSIST, AT A MINIMUM, OF THE FOLLOWING ROUNDS, namely :—

	H. Gun.	M. Gun.	F. Gun.	H. How.	M. How.	L. How.
Double shell :—	—	—	—	85536	51840	—
Common shell :—	68948	58080	764	8352	23904	27648
Shrapnell shell :—	3628	12960	5348†	1728	3168	—
Case shot :—	280	720	1528†	248	484	—
	72856	71760	7640	95864	79396	27648

or a total of 355164 rounds.‡

Of this ammunition, under ordinary conditions, half would be an ample supply with the train, as a store to commence the siege with; this gives, taking an average on the whole of each nature without reference to particular application :—

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* The firing of these pieces will of necessity be very variable.

† If mitrailleuses were substituted for some of the field guns, ammunition for them would replace a portion of this.

‡ In addition, there will be required spare barrels of powder, rockets, &c., &c. At Strasburg, "there were 241 pieces placed in battery outside the walls; during the 31 days over which the regular operations extended, these fired 193,722 rounds."—The Franco-German War, by Capt. Hozier.

During the whole of the war 1870-71, the Prussian Artillery sent into France but 800 pieces, with a supply of 973,901 rounds, which was not entirely consumed.

THE TOTAL NUMBER OF ROUNDS PER PIECE REQUIRED FOR OUTFIT, as :—

	H. Gun.	M. Gun.	F. Gun.	H. How.	M. How.	L. How.
Double shell :—	—	—	—	475	301	—
Common shell :—	615	484	16	46	139	384
Shrapnel shell :—	42	108	112	9	18	—
Case shot :—	3	6	32	1	3	—
	650	598	160	531	461	384

Which gives an average of 464 rounds per piece, taking all natures together, or 560, omitting field guns and light howitzers.*

III. CARRIAGES.

Each piece of ordnance of the train must be provided with a carriage for firing from, the description of which will vary with the nature and purpose of the piece; and, if the "fighting" carriage is not also a "travelling" carriage, an additional carriage must be provided for bringing the piece upon into battery.

From what has already been said under the head of "Ordnance," the latter, with their carriages, may, as regards transport, be divided into four classes, namely :—

1.—Pieces, which, individually, with their carriage, give a total weight approaching to, but not exceeding, the maximum admissible for transport,† namely 100 cwts.;‡ to which class belong the heavy guns and howitzers.

2.—Pieces, which, individually, with their carriage, give a total weight, such as to admit of transport with moderate ease,† namely, 80 cwts.;‖ to which class belong the medium guns and howitzers.

3.—Pieces, which mounted upon their carriages are very mobile, as field guns.§

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* 500 rounds are laid down for each piece of ordnance, of whatever nature, composing the unit of the British siege train. In the Russian train each piece of the *parc d'investissement* and of the *parc de l'attaque* is provided with 1000 rounds, except the 21 c.m. mortar, which has only 700.—See Revue d'Artillerie, May, 1877.

Kraft states, in reference to the quantity of ammunition necessary to commence a siege, that "the necessary store of ammunition has fluctuated in practice between 300 and 500 rounds per gun.

† That is for a team of 12 horses, no more than which can conveniently, or usefully, be employed together.

‡ Calculation gives us, at 120 lbs. tractive force, per horse, over ground opposing what may be considered an average resistance, a weight of 103¾ cwts. (on a siege carriage), which 48 men, exerting each a tractive force of 27½ lbs., can drag. The 8 in. S.B. of 54 cwt. weighed with its siege carriage, packed, 94½ cwt.; the 32 S.B. of 50 cwts., 88½ cwts.; the 64 pr. B.L.R. of 61 cwts., 102½ cwts.; while the 64 pr. M.L.R. of 64 cwts. weighs 113½ cwts.

‖ Calculation gives at 94 lbs. tractive force, per horse, a weight of 81·32 cwts., which weight 48 men, at 21½ lbs. each, can drag. The 8 in. S.B. howitzer of 21 cwts. weighed, on its carriage, 55½ cwts; the 40 pr. B.L.R. of 35 cwts, 81½ cwts; while the 40 pr. M.L.R. of 35 cwts. weighs 89 cwt.; the two latter carrying 5 and 6 rounds, respectively, of ammunition, which for siege purposes seems unnecessary.

§ The 16 pr. M.L.R. field gun, packed, weighs 42¼ cwts. which over ground opposing an average resistance, requires a tractive force of 536·7 lbs. or 30 men at 18 lbs. each.

4.—Pieces, which, individually, with their carriage give a total weight, such as to admit of their being, readily and quickly, carried by men from one position to another within moderate distance, namely: 310lbs.;* to which class the light howitzers belong.

In the first class, in order to obtain the piece of the greatest power, its weight, as already stated, must be a maximum and consequently that of its carriage a minimum, from which it follows that the piece must have both a "transporting" and a "fighting" carriage, because the lightest carriage of the latter description, having the requisite strength for its normal purpose, can never be made so light as one of the former description.† Taking the weight of the transporting carriage at 25cwts.† leaves 75 cwts. as the maximum weight admissible for the heaviest siege piece‡, or the heavy gun of the first position. The heavy howitzer, however, being for use in the second position, as well as the first, should be lighter to meet the greater difficulties of bringing into battery as the besieger approaches the fortress; its weight ought therefore not to exceed 65 cwts.‖

In the second class, by adopting the same arrangement, as in the first, namely, supplying a special transporting carriage, the medium piece may weigh 55 cwts. (i.e. 80 minus 25) while if a fighting travelling carriage is used the piece cannot exceed about 37½ cwts,§ as the latter carriage must weigh about 42½ cwt.¶ The latter arrangement is, in this case, the preferable as it enables the piece to be brought into battery more readily and quickly, a desideratum particularly in the second artillery position, while a piece, gun or howitzer, of 37½ cwts. will be of sufficient power for the work required from it, in supplementing the heavy piece of corresponding nature.**

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* From the necessarily small size of such pieces no more than 4 men can conveniently lay hold for carrying; this number, at 78 lbs. each, gives 312 lbs. The 5½ in. S.B. mortar weighed with its bed 168 lbs; the 7 pr. M.L.R. of 200 lbs weighs 424 lbs.

† For example the travelling siege carriage with limber for the 64 pr. M.L.R. of 64 cwt, weighs 45 cwt; a fighting carriage, such as the naval carriage and slide for this gun, fitted with transporting arrangement, would weigh about 38 cwts; while the platform wagon, fitted to carry the gun, weighs but 23¼ cwts.

‡ The 64 pr. M.L.R. of 64 cwts. is at present, the heaviest piece of the British siege train; the 15 c.m. ring gun, which weighs about 60 cwts, the heaviest of the German train. If fortresses of the future be armed with some guns in cupolas, no doubt, in order to disable them, pieces of far heavier weight than 75 cwts must, as a sine quâ non, be brought into position, a temporary railway being employed for the purpose.

‖ This giving with its carriage a total load of 90 cwts. would require a tractive force of 104 lbs per horse, or if 48 men were employed to drag it, 24 lbs each.

§ The medium piece of the British siege train, the 40 pr. M.L.R., weighs 35 cwts; that of the German train, the short 15 c.m. gun, about 30 cwts.

¶ The 40 pr. M.L.R. carriage weighs, empty without ammunition boxes, 43 cwts, but is made stronger than necessary for the 40 pr. in order to take also the 6·3 howitzer when required.

** But when exceptional circumstances prevent the use of heavy pieces, and medium have to take their place, it is desirable as already mentioned, that the latter should be as powerful as possible, they should therefore then, gun and howitzer, be of 55 cwts. Such pieces would of course be of larger calibre than those of 33½ cwts, though both are classed as medium.

In the fourth class, following the usual proportion of weight between a piece of the description indicated and its carriage, the weight of the former is limited to 150lbs.*

We have now to determine, generally, what the descriptions of fighting carriages should be, viz: whether adapted for the piece to fire through a deep embrasure, shallow embrasure, or overbank; and, if for the latter, whether they should be arranged for the piece to recoil under cover or not.

In the first artillery position it will generally be possible to construct the heavy gun batteries so as to be well hidden from the enemy's view, for owing to the great distance of the position from the fortress, not only will natural undulations of ground intervene, but walls, gardens, trees, &c., due to the impossibility of keeping such an extent of ground free from cultivation, while the power of the guns and the nature of their work will permit considerable choice of site for them, Hence in these batteries† comparatively deep embrasures are admissible: for, not being seen by the enemy they cannot assist his aim, and, as but small angle of traverse is required for the guns, they need not be wide mouthed to weaken the parapet. That the latter may be cut away as little as possible, the carriage should give all the height to the axis of the gun which facility of working a heavy piece and the details of its own construction will conveniently permit.‡

Howitzers of the bombarding batteries, including the light howitzer in the second as well as in the first position, being only fired at high angles of elevation can be mounted on low carriages behind a high parapet, in fact, upon "beds," as mortars, of merely sufficient height to admit of the requisite elevation being obtained from the piece.

Howitzers for enfilade (curved) firing being used in the second as well as the first position must be mounted on the description of carriages suited for the former.

In the second position the besiegers batteries cannot be so placed as to be hidden by natural objects from the enemy's view, therefore, in this position deep embrasures, or even any embrasures, however shallow, which facilitate the enemy's aim are inadmissible, unless the batteries can be sufficiently masked by screens of earth thrown up in front,‖ while, even then, any but very shallow embrasures, or mere troughs in

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* The 7 pr. M.L.R. weighs 200 lbs, and its bed for siege purposes, 224 lbs.

† Speaking of the 1st batteries, Kraft says, "We have had batteries which the enemy has endeavoured to search out with his fire for days and weeks but has failed and they suffered no losses and produced excellent effects."

‡ In addition to this, the deeper an embrasure is, the more easily is it ruined by shell and the less easily re-established.

The height of axis of the 64 pr. M.L.R., on its siege carriage is $4'\text{-}5''$, which permits it, at 5° of depression, to fire over a sill of $3'\text{-}4\frac{3}{4}''$; on a sliding carriage and platform, such as in use in the navy, its height would be $3'\text{-}1''$ and it would fire over a sill of $2'\text{-}1''$.

It will generally be possible to leave the earth under the ground platform higher than the remainder of the terreplein of the battery and so raise the height of the piece to the greatest admissible for working, if that height be not given by the carriage as would be the case were such as the naval carriage used.

If heavy guns have to be used in the future for breaching or demolishing armour plated works they must be mounted on carriages to recoil under cover.

‖ In the Eastbourne experiments such screens were used apparently with success.

the superior slope, would seem objectionable from the ease with which heavy or medium rifled shell would, on reaching,* destroy them and the parts of the parapet adjacent.†

With batteries of howitzers for enfilading, demolitions, &c., the pieces being fired at some elevation and requiring for their work but small degree of lateral traverse screens may be effectively used, but with gun batteries, the pieces of which, not only must command the ground to their front, but in their fire (direct) upon the fortress be capable of changing the line through a considerable field in order that they may concentrate upon a particular object or shift from one object to another, the case is different and any screen that could be admitted would hardly be sufficient to mask the battery. We therefore conclude that while the carriages for howitzers of the second position may be adapted for the pieces to fire through shallow embrasures,‡ those for the medium guns must be overbank.‖ For field guns employed in the second position for lodgements, and in the first for emplacements, it seems however hardly necessary to provide such special high carriages, for, when the lodgements are made the enemy's artillery fire will be subdued and protection against small arm fire may be obtained by the use of mantlets, and in emplacements the guns may be used overbank by constructing the terreplein of the battery to suit.§

The gunners working the guns mounted upon overbank carriages will to a very great extent be protected, though the pieces will be exposed,¶ and only by the use of carriages so arranged that the piece will recoil in them under cover for loading, can the men and the guns also be perfectly protected. Under ordinary circumstances** there does not, as yet, seem any absolute necessity for such carriages as the latter; this

* Batteries of the second position, even with screens, will be more easily reached than the heavy gun batteries of the first position, for, as already mentioned, the enemy may even fail to search the latter out.

† A shallow countersloping embrasure will not much affect the strength of the parapet, see Plate I, fig. 2. It might be said that such embrasures presenting an unbroken exterior crest to the enemy would not facilitate his aim, (even if not screened), but if he could see the interior crest, which in all probability he would be able to do, it would be sufficient for his purpose.

‡ It may be objected that this is giving two natures of carriage to each howitzer, viz., one for high angle fire and one for curved fire, but this would be more than balanced by the saving of weight, cost, &c., in using a special carriage for the former purpose and it is to be remembered that the bombarding howitzers much outnumber those for enfilade, &c. Again it only amounts to what we had in the S.B. system, namely, a bed for mortars and a carriage for howitzers. Possibly a construction of carriage might be designed suitable for both purposes by some slight conversion which could be carried out on the spot.

‖ The German and Belgian siege carriages are now of this type.

§ Kraft, in his pamphlet on sieges, however states, with regard to emplacements against sorties, "These have not turned out very well when armed with field artillery as they have only an interior slope 3′ in height and consequently lose much of their matériel in course of time. It would be better here to employ the 6 pr. (9 c.m.) siege gun, for which there would otherwise be no use at the commencement of the siege."

¶ This is sometimes raised as an objection against such carriages, but we suppose the besieger does not, as a rule, depart from the fundamental principle of assuring to himself superiority of fire in the number and nature of his ordnance, and therefore that he is able to fight, not at disadvantage, the enemy's guns mounted in the same manner as his own. Again any such objection applies with greater force to carriages arranged for the pieces on them to fire through embrasures.

** For breaching armour-plated works by direct fire, as already stated, they will be necessary.

will arise when, as Brialmont puts it,* the problem is completely solved and the besieged has "a carriage, simple, solid, little costly, which permits of firing over 2·5m. (8·2ft.) without exposing the piece longer to the fire of the enemy than necessary for pointing and firing," for then the besieger must adopt the same appliances in order that he may not be at a disadvantage or unable, as easily as heretofore, to assure to himself the necessary superiority of fire.

With regard to the carriages for the heavy guns of the first position it remains to say that these being for comparatively deep embrasures should be of the "sliding" type on a low traversing platform† or of the "common standing" type; of which the former is the preferable on account of the facility and accuracy with which the piece mounted upon it can be worked.‡ Like the heavy guns the carriages of the heavy howitzers should also be of the sliding type, the platforms being made higher to suit the less depth of embrasure.

Assuming that, in general, a railway will be available for bringing up the materiel of the siege train to a point not far distant from the park, it is not necessary to provide a transporting carriage for each individual piece of the heavy guns and howitzers, one for every two pieces would seem sufficient.

Summing up and adding 20 per cent.‖ spare we have :—

THE TOTAL NUMBER AND NATURES OF CARRIAGES FOR THE ORDNANCE OF THE SIEGE TRAIN, AS :—

		H.Gun.	M.Gun.	F.Gun.	H.How.	M.How.	L.How.
Fighting.	*Behind bank - - beds*	—	—	—	79	48	43
	Deep embrasure, - sliding with platform	67	—	—	—	—	—
	Shallow embrasure ,,	—	—	—	29	—	—
	,, *travelling*	—	—	—	—	55	—
	Overbank, ,,	—	72	—	—	—	—
	Field, ,,	—	—	29	—	—	—
Transporting,		33	—	—	54	—	—

which gives a total of 509.

To complete the train, to this number, have to be added carriages for the transport of ammunition, ground platforms, mounting and other stores, with respect to which it is sufficient to say, that, assuming as

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* Traité de Fortification Polygonale.

† These should be fitted for a transporting arrangement to facilitate bringing them into battery (with the carriage mounted) and a transporting arrangement issued with them in the proportion of one to two platforms.

‡ The weight of the standing carriage for the 64 pr. M.L.R. is 17¼ cwts, and of a common ground platform 36 cwts, or together 53¼ cwts; that of a sliding carriage and platform would be about 35 cwts, and its ground platform about 13 cwts, making a total of 48 cwts.; the present siege carriage, without limber, is 33 cwts, which, with the ground platform of 36 cwts, gives 69 cwts.

‖ Carriages being more vulnerable than ordnance, a greater percentage of spare is required.

before mentioned railway conveyance to be available up to a certain point, carriages have only to be supplied to bring the matériel from that point to the siege park and again, as required, from the park to the batteries an estimate of which is readily formed upon the probable quantity necessary for first supply and daily consumption as basis, by allowing 2 tons per transporting carriage for horse or traction engine* draught on road and 1 ton per truck if narrow gauge rail† be used.‡

IV. MISCELLANEOUS STORES.

Under this head are included ground platforms and all other stores which an artilleryman requires for the use and maintenance of his guns, an attempt to estimate which would, for our purpose, be but going into unnecessary and uninteresting detail. We may mention that among the smaller stores should be means for telegraphic communication between an observer sent forward from a battery and the battery itself, when it is necessary and possible to do so, for obtaining accuracy of fire, as in the case of breaching by curved fire and taking observations from the crowning; for this purpose Count Bylandt-Rheid tells us,|| "the employment of the, so called, clock telegraph, as used by the Military Committee and by some divisions of artillery when practising is to be recommended."§

Whatever means are employed for this purpose a proportion of the artillerymen of the train should be skilled in using it, for a man of any other branch of the service, for example, an engineer, will lack the necessary technical knowledge to be able clearly and accurately to give to the battery the information required.¶

CONCLUSION.

Examining the results of the experiments, bearing upon the attack and defence of fortresses, made, at home and abroad of late years and considering what has been said upon the matériel of the siege train, it must be apparent to all that much yet remains to be done in this direction.

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* A traction engine, such as now adopted in Italy for the transport of the 2nd line, of 6-horse power, weighing 7 tons, can draw 8 to 10 carriages, of 2 tons each, on a road in good state up ramps under 4 in 100. "During the war of 1870-71, the Germans utilised between Manteuil, where the railway of l'Est had been cut, and their siege park established at Villacoublay, a traction engine to supplement the insufficiency of the columns of the park, and to aid the transport of the necessary matériel for the bombardment of Paris."—Revue d'Artillerie, tome vii.

† A locomotive for such could draw, allowing for curves and easy ramps, about 8 tons of load.

‡ When the necessity arises for heavier siege pieces than those now in use, or exceeding the limit of 75 cwt. which we have laid down, there will not be much difficulty in doing it by the use of such mechanical means.

|| On curved fire, by Count Bylandt-Reidt, Major General in the Austrian service.

§ Certainly the method of signalling by discs, &c., is impracticable for such purposes.

¶ It might be said the engineer could work the telegraph, the necessary information being given him by the gunner, but this would be but introducing an unnecessary complication—a divided responsibility—which is always an evil; besides which, it would never answer for the artillery, or any other arm, to be dependent in any purely technical affair, upon another arm.

To speak of our own train only, as it is now laid down, are we in a position to say from practical experience what the guns of that train can do in dismounting, in breaching, by curved or direct fire—at what extreme ranges—under what limiting conditions—they may be used and with what expenditure of time and ammunition? or can we say how best they may be mounted? These are questions, which, as it were, have two sides to them an active and passive; in other words, in dealing with the active effect producible by the ordnance of the train on the defence it will not do to omit consideration of the effect, passively received, of the defence upon the ordnance. The wisdom of General Todleben, in this respect, is to be admired at whose instigation, in Russia, combined exercises for artillery and engineers have been of late years carried out. In England these two arms of the Service can hardly be said either in annual routine or experiment to be brought together; at Shoeburyness there is the R.A. School of Gunnery, at Chatham the R.E. School of Engineering completely separated, to say the least, by the rivers Thames and Medway. Has the garrison artilleryman, unless exceptionally, the chance of becoming practically acquainted with the improvements made in defensive and siege batteries or has the engineer a chance of learning what practical effect the guns of the siege train will have upon the works he throws up, or of seeing how best he may meet that effect? Why should not artilleryman and engineer meet, once a year, on common ground and be pitted one against the other, under conditions as nearly as possible approaching those of war? the cost would be a mere nothing, while the profit to each, not only at the time, but for fitness to meet the varying circumstances of war would be incalculable, as an example of which we may cite the fact that the success of the Germans in breaching, &c., by curved fire at Strasburg was to a great extend due to the work being carried out under the supervision of the officer who had previously been engaged in the experiments in curved fire at Silberberg.

March 29th, 1877.

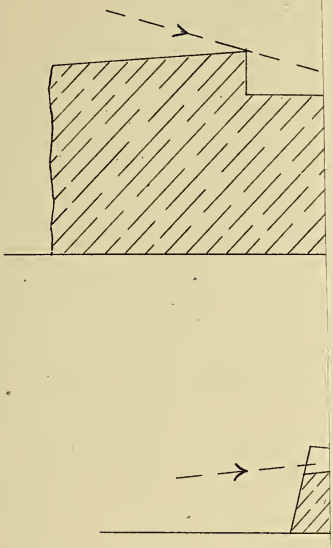


FIG 3.
Scale $\frac{1}{3000}$

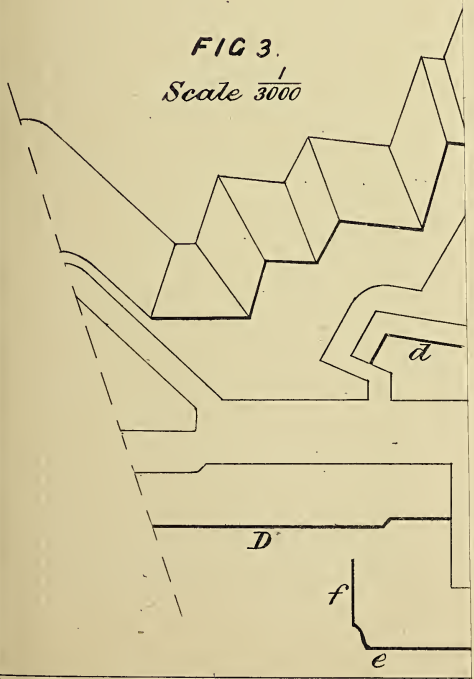


FIG 1.
Scale $\frac{2}{3}$" = 32·809' = 10 m.

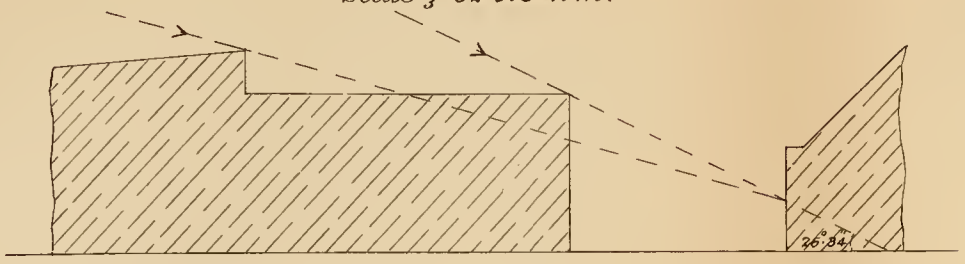
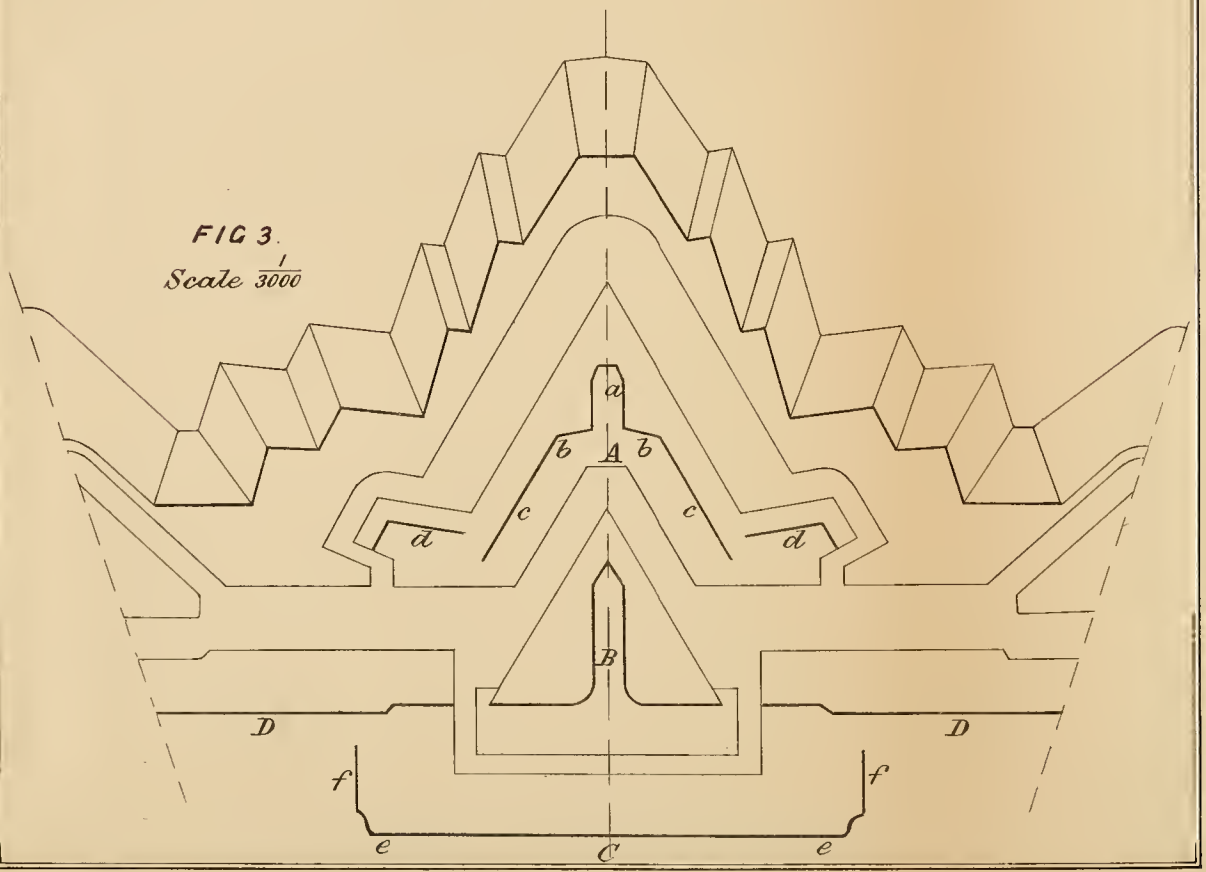
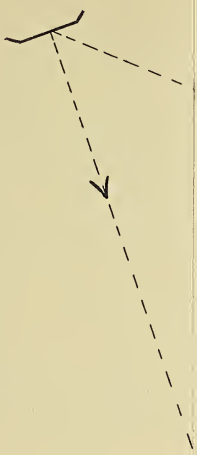
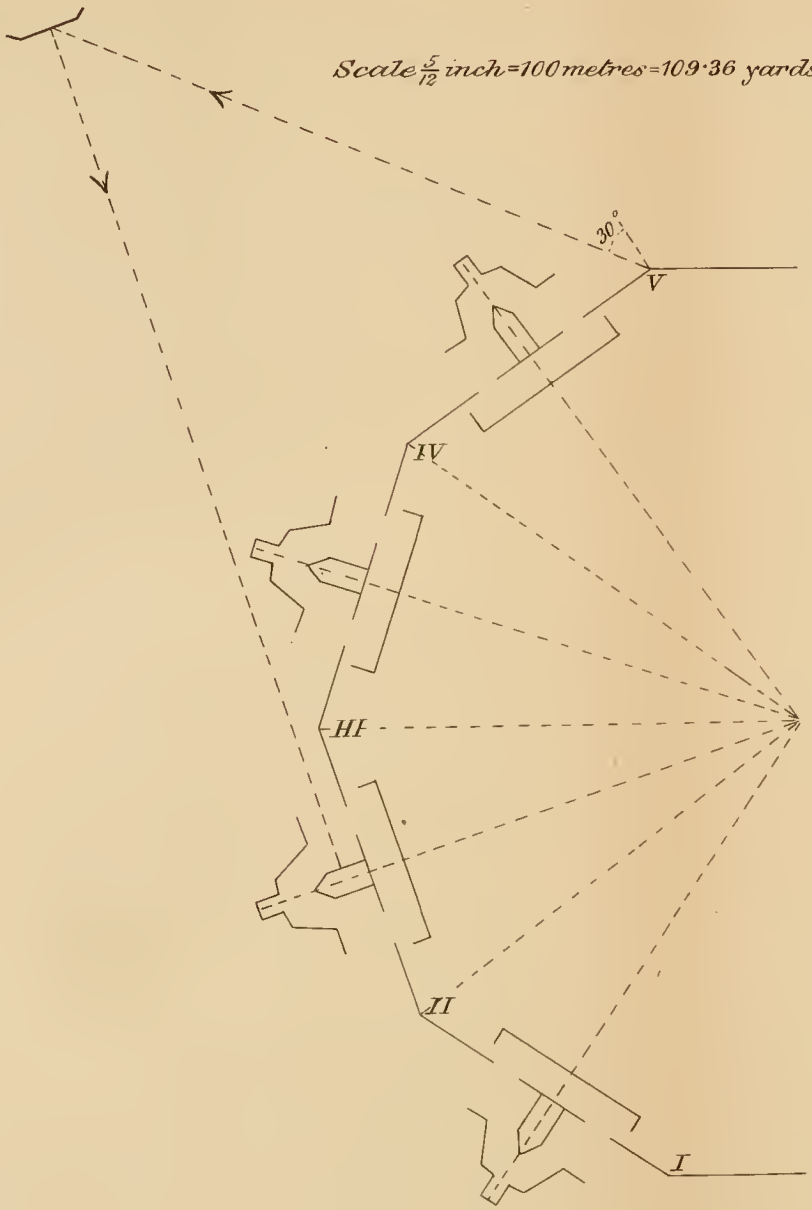


FIG 2
Scale $\frac{2}{3}$" = 10'

FIG 3.
Scale $\frac{1}{3000}$






Scale $\frac{5}{12}$ inch=100 metres=109·36 yards.
30°
V
IV
III
II
I

METHOD OF ARMING CLIFF END BATTERY, ISLE OF WIGHT, BY HAULING THE GUNS UP AN INCLINED TRAMWAY,

BY

CAPT. W. R. RUDGE, R.A.

A new method of arming elevated batteries was proposed by the Heavy Gun Committee, of which the following is a short description, with an account of the experiments carried out under my superintendence.

Cliff End Battery stands 120 feet above mean sea level, on the West Coast of the Isle of Wight, nearly opposite to Hurst Castle. The cliffs are principally clay, and slope down to the sea in broken inclines. A tramway of rails laid on longitudinal and transverse sleepers has been constructed from the top of the cliff to the bottom, the gradients varying from 1 in 6 to 1 in 3. The steepest inclines being close to the top of the cliff. A pier runs out about 30 yards from the shore line, so that a barge drawing about 4 ft. 3 in. of water may be brought alongside at high tide. The pier has a staging for men to work on. The rails are laid at 4 ft. 2 in. track.

The barge takes the ground as the tide recedes, and the rails on the pier are then about 1 ft. above the level of the deck of barge.

The incline of the tramway commences on the pier, about five yards from the sea wall.

A special carriage has been constructed by the Royal Carriage Department for the service, and it consists of two cradles of iron, having a pair of wheels each, adapted to travel either by road or rail. These two cradles are connected together by rectangular iron bars, which pass through the upper portion of the cradles, and can be adjusted at different lengths by means of bolts and shackles. The hind cradle is hollowed in the upper surface so as to fit the breech coil of a 38-ton gun, and blocks are supplied to adapt this hollow for the breech of an 18-ton gun. The front cradle is hollowed to take the first coil.

The brake gear is fitted on the hind cradle below, and consists of jaws, made to act on 9 in. hawsers, laid between the rails from the top to the bottom of the tramway. The inner jaws are connected to a right and left-handed screw, worked by a sprocket wheel. The outer jaws are fixed.

The gear is set in action by the sprocket wheel, resting on a central baulk laid between the rails, and should there be any backward movement of the carriage, the teeth on the sprocket wheel biting into the baulk move the screws and cause the jaws to nip the hawsers. When the carriage moves upwards, the jaws are released by the sprocket

wheel disengaging from the baulk, and the hawsers pass freely between them. The hawsers are kept in place by guide rollers. The wheels of carriage are fitted with skid blocks which are self-acting on the rails, skidding the wheels whenever there is any backward movement.

The front cradle is nearly similar to the hind, except that it has no locking gear, and it is made in two parts so as to pivot when used by road, these parts can be locked together for use on rails.

Loops and shackles are fitted for the purpose of draught and lashing. The gun is secured to the carriage by lashings round the cascable and trunnions. The length of the carriage should be adapted so that about two-thirds of the whole weight may be on the rear cradle.

The winches are arranged in two sets, one set rather more than half way up the incline, and the second set at the top. Each set consists of a 5-ton iron winch on either side of the rails, about eight yards from them, and opposite to each other, with a 2-ton iron winch in rear of each. The 5-ton winches are fixed on frames of wood, and the frames sunk into the earth, picket posts being driven in each angle as a further security. The handles of these winches are made very long so as to allow eight men to work at each handle if necessary. They have slow and quick motion, and brakes. The chains are passed round the drums of these winches three times, and led to the 2-ton winches, about five yards in rear. The 2-ton winches are fixed to wood frames placed on the ground and secured by picket posts driven at the angles. These winches haul in the slack of the chains after leaving the front ones, and prevent "surging." About four men are required to hold on to each chain in rear of the 2-ton winches.

The hauling chains are small link, of best wrought iron, 1 in. in diameter. The blocks are of iron, adapted for the chains, and are made as "snatch blocks." The holdfasts for standing ends of hauling chains consist of wood baulks buried, with chains round them leading to the surface. At the top of cliff, one holdfast, which is made very secure, takes the standing ends of the chains as well as the ends of the 9 in. hawsers for locking gear. When using the lower set of winches half way up the slope, it was impracticable to make a good holdfast between the rails for the standing ends of the chains, so two holdfasts were made, one on each side of the rails, and a long but strong chain made fast to both, to this the standing ends of chains were secured. Shackles and bolts were used to connect the chains, blocks, &c.

Single blocks were attached to the gun carriage, and the chains rove through them. The chains were led off to the winches by means of other single blocks, for which holdfasts were made by heavy anchors buried, with skids across the flukes.

The gun is brought up by two chains, worked by the winches on opposite sides of the tramway, care being taken that the strain is as nearly equal as possible. When brought up to the lower set of winches, and on a level part of the rails, the carriage is carefully scotched and skidded, as the chains have to be cast off and shifted to the upper set of winches and holdfasts.

An 18-ton gun was first brought up to test all the arrangements.

A 38-ton gun was then brought on a barge to the pier head, landed by parbuckling, then slewed by means of a 50-ton jack placed under the C.G., the muzzle being hauled round steadily by a winch and tackle from the shore. When in position, it was raised by jacks high enough for the carriage to be run under it, lowered and firmly lashed to the carriage by cascable and trunnions. The chain tackles were then attached, and the winches set in motion. The quick purchase was used along the pier and up the slight inclines, but the slow purchase had to be used up all the steep ones. The winches were worked by reliefs, about ten minutes at a time. When the chains require shifting on the drums of the 5-ton winches, they are "stoppered" by gun metal blocks made to fit on the chains, the outside being conical; these blocks slide into conical rings or stoppers, which are firmly secured. The chains can then be shifted without danger.

The number of men employed in bringing up the 38-ton gun was as follows:—

Attending to blocks, &c., on carriage	2	men.
To work 5-ton winches, two reliefs of 12 for each winch	48	„
To work rear winches, 6 men for each winch	12	„
To hold on to running end of chains in rear of 2-ton winches, 4 each chain	8	„
Total	70	men.

By working in short reliefs the winches were kept going much quicker. Extra men had to be put on when working up the steepest inclines.

The average rate of a 38-ton gun was 11 yards an hour, taking into consideration all stoppages for "stoppering and shifting falls," shifting chains to upper holdfasts, winches, &c. With an 18-ton gun, about 16 yards an hour was obtained, as the quick motion could be more frequently used. A good deal of time was occupied in shifting the chains to the top, as they had to be carried up by hand.

When brought to the top, the gun was taken off the carriage by jacks and parbuckled into the battery, and the carriage lowered for another gun.

The total time occupied in hauling the guns from end of pier to top of cliff were—

18-ton gun.....	11 hours.
38 ton gun.....	16 hours.

ON THE ATTACK AND DEFENCE OF A POSITION,

BY

CAPTAIN E. CLAYTON, R.A.

The following paper took its origin from a suggestion made to the writer that a brief exposition of the principles that have been deduced from recent experience for the attack and defence of a position might be useful to officers, especially captains, preparing to pass the examinations for promotion prescribed in G.O. 66 of 1st November, 1875.

The writer has freely consulted the works of the principal modern authorities on Tactics, but he is, of course, alone responsible for the use he has made of the materials at his disposal.

An example has been added to show the application of the principles enunciated to an actual piece of ground in England, with bodies of troops organized as in the English army. It is not put forward as the only, or even as absolutely the best, solution of the problem given, but merely as one fairly good and fairly probable.

Attack.

In the first place, let us take a general view of the probable course of an attack; we can afterwards go more into detail about the action of the different arms.

An army in the neighbourhood of an enemy will have its front usually covered by bodies of cavalry, whose duty it will be to screen and protect the movements of the troops behind them, while seeking to obtain all information possible about the enemy. In the Franco-German war this task was carried out with eminent success by the German cavalry, the French, at all events in the earlier part of the war, making little or no attempt to employ their cavalry in similar duties. But it must not be expected that in future wars the cavalry on either side will be able to effect its purpose with so little opposition as the Germans encountered. Both parties will try to play the same game, and hence, unquestionably, the first phase of a campaign will be a series of cavalry actions. The cavalry that is beaten in these first encounters will have to fall back to the protection of the advanced guards composed of all arms which will precede the main armies, and the victorious cavalry will gain its object of screening its own army and obtaining more or less information about the enemy. If the cavalry of the advancing army is successful, it will continue to push on, driving before it the defeated horse of the defenders. Eventually, it will come upon hostile infantry. If these are only in small force, part of the cavalry will dismount, and with the aid of its horse artillery attack and drive them off, for one duty of the advanced cavalry

is to prevent the troops behind from being delayed by insignificant bodies of the enemy. Sooner or later, however, the actual position occupied by the enemy will be approached and the advance of the cavalry will be entirely stopped by meeting with hostile posts too strong to be dislodged without the aid of infantry.

When this occurs, the approach of the advanced guards of all arms must be waited for.

Should the cavalry of the advancing army be defeated in the preliminary actions, the movements of the army will be much retarded, as the reconnaissance of the country will have to be effected by the infantry of the advanced guards. Eventually, however, as in the former case, the advanced guards will come in contact with the outposts of the enemy in position.

When the enemy has been discovered it will next be necessary to reconnoitre his position in order to enable the General to decide whether he will attack, and, if so, in what manner. Under certain circumstances, it may be possible for the cavalry and horse artillery to obtain sufficient information, but this is not probable unless the enemy is exceedingly unwary and allows himself to be needlessly tempted into showing his hand. In ordinary cases it will fall to the lot of the advanced guards to obtain the needful information. For this purpose an attack pushed more or less home will have to be made. This attack by the advanced guards will be especially directed towards the flanks of the enemy's position, in order to discover where they lie and the chance of successfully turning them, for the frontal strength of positions is so great with the present weapons, that there is nowadays a great tendency to try and turn one or both flanks, in order to avoid, as far as may be, the loss incident upon attacks in front. The artillery of the advanced guards reinforced, it may be, from the bodies of troops behind, will play a principal part in this preparatory action, as its long range fits it for carrying on a demonstrative and delaying action, but it may be necessary to push on an infantry attack if the artillery fire alone does not suffice to make the enemy show his dispositions.

Whilst this reconnaissance by the advanced guards is proceeding, the General will make up his mind as to whether he will attack, and, if so, on what portions of the enemy's position the chief efforts shall be directed. As soon as he has determined on the general dispositions to be made, the mass of the artillery will be brought forward into action.

It may be taken as an axiom under modern conditions of fighting, that no attack will succeed until the fire of the defender's artillery has been considerably weakened, if not absolutely silenced, and the points on which the serious attacks are to be made have been well searched by artillery fire to destroy material defences and obstacles, render localities untenable, and shake the defending troops. To do this effectually will require a considerable time. A considerable time will also be required for the army to deploy from its order of march nto order of battle. It is desirable that these two processes should

go on simultaneously. On this account the greater part of the artillery of an advancing army should march not far from the head of the column, so that it may be brought up as soon as the plans of the General are made, in order that the necessary artillery preparations for the attack may be commenced without delay while the deployment of the main body is carried on under cover of the cannonade.

After the advanced guards have effected their task of reconnaisance, they will take up some position with defensive capabilities, wherein they may be able to hold at bay any offensive movements of the defenders, and protect the artillery from danger.

When the artillery of the attack has been brought up into its first position, an artillery duel is pretty sure to be the next stage of the battle. The attacking artillery must try to silence the artillery of the defence, or the infantry attacks must fail; while the defender's artillery will endeavour so to employ the original advantages which they possess, in having been able to previously entrench themselves and measure ranges, to prevent the assailants from establishing a superiority in artillery which will enable them to carry out successfully the preparations for the infantry attack. On the issue of this artillery duel will mainly depend the possibility of an attack being successfully delivered. If the attacking artillery cannot obtain a superiority, an attack will be pretty sure to fail. The full strength of the artillery will therefore be brought forward at once, to endeavour to obtain the mastery. The retention of artillery in reserve in the case of attack seems neither desirable nor necessary, inasmuch as recent experience points out that it is not impossible to withdraw batteries from action, and move them, if required, to other parts of the field, even under effective hostile fire.

As soon as the artillery fire of the defence begins to slacken, some part of the assailant's guns will be turned on the points where the decisive attack is to be made, either some parts of the main defensive position, or some advanced points which must be captured before the main position is assailed.

In the meantime the deployment of the army has been taking place, in accordance with the plans for attack of the General.

When it appears to the General that the fire of the defenders has been sufficiently got under, and the points selected for attack have been subjected to an adequate cannonade, then the infantry will be ordered to advance to the attack. Experience in late wars has shewn that an advance of infantry in closed bodies of any magnitude is impracticable over ground exposed to an effective fire from the defender's position. It is therefore necessary to advance in such a manner as to minimize the effect of hostile fire. This will in the first place be effected by choosing for advance such portions of ground as give the greatest cover from the view and fire of the enemy. But at some time or other, an advance over open ground is sure to be necessary, and the best means of effecting this appears to be by advancing in a line of men at open order, either continuously or by successive short rushes, either of the whole line simultaneously, or of portions alter-

nately, making use as far as possible of any cover the ground may afford. Between the rushes the men will lie down and keep up a steady fire. This first line will be followed by a line of small bodies, whose duty is continuously to feed the first line, and keep its strength up to the maximum that can find space to use their arms, which may be taken as a line of men at from a yard to a yard and a half interval. These small bodies should advance in the formation most suited to each of them at the time. Behind these again will be required a further line, to be brought up to the firing line at the moment when the assault is to be delivered, to give sufficient weight to the charge. This line will also be obliged to suit its formation to circumstances, but a general rule should be observed, that extended formations for the rear lines should only be adopted from necessity, and the men should be kept in hand and in such a formation as to render their control easy as long as possible. These three lines will then gradually press on towards the enemy's position, which they will take some time to approach, the action swaying backwards and forwards with the efforts of the two sides. Eventually, if all goes well, the firing line will be able to establish itself within reach of a rush at the enemy's position. Then a rapid fire will be carried on for a few minutes, whilst the bodies in rear close up, and then the word will be given for the assault, when, if the preparatory fire has been efficiently carried on, the position should be won. The first three lines are expected to be sufficient to carry through the attack of the selected point of assault. But something more has yet to be thought of. If the assault is successful, its carrying out will be sure to throw the troops that make it into confusion, and a counter-attack delivered at that moment would be very dangerous, unless it was provided for. Therefore a further reserve is necessary, to repel any counter-attacks made at this critical moment, and to secure the points won. In case of a failure of the assault, a reserve is equally necessary to secure the retreat of the repulsed troops.

Whilst the advance thus sketched out of the infantry is taking place, the artillery will most likely have to leave its original position, and move onwards. It is probable that the advancing infantry will mask the fire if this move does not take place; but even if this should not occur, it will be desirable to move forward a portion, at all events, of the artillery, on account of the cheering effect that the close support of guns gives to the sister arms. A reference to the attack on the Rotherberg at the battle of Spicheren, and the action of the artillery of the V. and XI. corps at Wœrth, will show this. Under these circumstances, artillery must not be chary of venturing even into effective musketry fire, remembering that their losses will be compensated for by a victory gained.

It is hardly to be expected that during the progress of this action much opportunity will offer for the employment of cavalry; but it will have a duty to perform in guarding the flanks of the attack, and the example of Von Bredow's brigade at Mars la Tour, shows that occasions may occur when a timely charge of cavalry will bring about

the most momentous results, if it is a question of gaining a certain amount of time. In such a case a noble self-devotion on the part of the cavalry may change the whole aspect of a battle.

In making the arrangements for an attack, it is desirable to point out distinct portions of the enemy's position as goals to be aimed at by distinct parts of the attacking line, such as divisions, brigades, or battalions. If the enemy should occupy several lines of defence behind one another, a portion of the first line will be the first thing aimed at, and when possession is obtained of this, the troops should be re-formed, and fresh arrangements made for further advance against the remaining hostile positions.

It has already been said that in all probability the attempt will be made to turn one or both flanks of the enemy's position. When the troops detailed for this task reach the position from which the advance against the flank is to be made, it will be carried out as an attack in front. A portion of the artillery will be moved from its first position as the flank attack developes itself to support it.

Before proceeding to consider rather more in detail the action of the different arms in an attack, it will be desirable to throw a glance back to the beginning of the combat, in order to notice the considerations which will guide a general in deciding upon his plan of attack.

The effect of fire from troops occupying strong points, such as villages, large buildings, woods, or entrenchments, is so great that the efforts of attacking troops are certain to be attracted towards such points, especially as the capture of any one of them will certainly exercise a great influence on contiguous portions of the enemy's line. Therefore, a modern battle is sure to resolve itself more or less, according to the nature of the country, into a series of fights for localities, and the general of the attacking force must bear that in mind when making his dispositions. If in some part of the defenders' line there is a portion of open ground between two points, such as a wood and a village, it will be of no use to direct an attack upon the open portions of the line, for the troops as they advance will be certain to edge off to the attack of the strong points. On some one or more, therefore, of these strong points of the enemy's line will the serious attacks have in ordinary cases to be directed. In the selection of the particular points to be attacked the following considerations come into play. First and foremost, the point selected must be capable of being reached by a powerful fire of artillery to prepare the way for the assault. Next, the possibility of advancing without suffering excessive loss must be taken into consideration; thirdly, the possibility of directing conveying fire on the point of attack gives a great advantage; and lastly, the question has to be considered of how far the capture of any particular point will further the general scheme of the assailants It has already been mentioned that now-a-days that there will generally be a great tendency to attack the flanks of a defensive line; this tendency arises from a combination of the above considerations. The flank of a line is the weakest part, and is most likely to offer the assailants the two advan-

tages of the power of bringing converging fire upon it, and of advancing with less loss than in a frontal attack, and if it is broken in upon the rest of the line is sure to be more or less seriously compromised, and an attempt to repair the injury will meet with great difficulties, as the reserves will probably be less favourably placed for immediate action on a flank than in the centre.

In former times there was always danger in weakening the centre of a line of battle for the purpose of making outflanking movements, but this danger is considerably lessened at present. The distance apart at which armies will now form their lines of battle is so great that it will be difficult for the defenders to see whether part of the assailants' line has been dangerously weakened or not, and they will be chary of leaving their strong position for a counter attack which will have to be pushed a great distance to be effective, in ignorance whether they will not find after all the enemy in sufficient strength to meet them. And should circumstances lead to the development of masses of artillery about the centre of the attacking line, the front will be so strengthened thereby that other troops may be freely drawn from this point to strengthen flank attacks, as was shown very clearly at the battles of Woerth and Mars la Tour.

Upon a review of these considerations, the general will decide upon his plans, and indicate the first positions for the artillery, and after sufficient time for effective artillery preparations, he will send his infantry forward to attack in the manner already sketched out. He should always retain a certain number of troops under his hand as a reserve to be employed as circumstances may render necessary.

We have now to consider a little more in detail the management of the different arms in an attack.

First, with regard to the *infantry*. In all cases the General in Chief will decide first what troops he will keep as a general reserve, and will then assign particular objects to be sought by the different units of the troops he sends forward to the attack, be they corps d'armée, divisions, or brigades. Then each of these units will be formed in two lines, or perhaps, in the case of large forces, in two lines and a reserve, and further, each battalion in first line will advance in three parts, according to the principles already laid down, the three parts being the fighting line, the supports, and the main body.

Appendix (E) to G.O. 34 of 1st May, 1877, lays down formations for the attack of infantry organised as in our army, which carry out the principles that have been above enunciated. There is one point, however, in which it appears that a modification of, or addition to, the instructions, would be desirable. It is apparently intended that when the fighting line is reinforced by the companies in support, the men who are sent to reinforce should double in with the men of the companies in the fighting line, thus mixing companies together. It is no doubt true that this mixture cannot be entirely prevented, but it is desirable that it should not take place more than is unavoidable, and it would seem preferable instead of distributing reinforcements equally along a fighting line weakened by casualties, to try and take advantage

of the tendency of men to collect in groups by training the non-commissioned officers to make themselves the centres of these groups, and close them towards their companies, whereby openings would be left for sending up reinforcements in coherent bodies, and the companies would be kept distinct under their own officers.

Each battalion in first line should have some definite object in the enemy's position pointed out to it as the first thing to be gained. When this is won, the retiring enemy should not be pursued, except by the fire of the artillery, or by cavalry, until the infantry has been re-formed, and new arrangements made for further action. The second line will follow the first, to secure the points won, if the attack is successful, and protect the re-forming of the troops who actually made the assault; and if the attack fails, to cover the beaten troops from an echelon position further back, in conjunction with the artillery. Under circumstances that permit of it, the second line may be employed to infuse fresh energy into an attack that seems scarcely strong enough to succeed without further aid. An officer commanding an infantry attack, should remember that although it is desirable to keep troops in hand as a reserve as long as possible, yet he should send in his last company rather than see the attack stopped. It is for the superior officers to see that assistance is sent where necessary; in fact this is often the only way in which they can influence a fight when once begun.

Let us next turn to the *artillery*. The batteries of the advanced guard should take up their position to protect the deployment of the advanced guard, if possible not far from the road by which the troops are coming up, but in such a situation as not to expose the advancing columns to the danger of being struck by projectiles aimed at the guns. They will fire at the defender's artillery to divert the attention of the latter from the troops of other arms as they come up, and co-operate, as may be required, with the advanced guard in making reconnaissance of the enemy's position. When the General has made his plans, the mass of the artillery will be brought up into position. In many cases, as was seen at Woerth and Gravelotte, for instance, the nature of the country will dictate where the first main artillery position is to be, but if there is any power of choice, then such positions should be selected as will enable fire to be concentrated at effective ranges on the points selected for attack, and on such of the enemy's batteries as bear upon the ground the attacking troops will have to pass over. From this position the fire of the artillery will first be directed to subduing the fire of the artillery of the defence, and when this has begun to be effected, the attention of part of the guns will be directed to cannonading the point of attack, to prepare the way for the infantry. When the latter advance, it will be advisable at some time or other to move guns forward to prevent their fire from being masked, and to give more immediate support to the infantry. As during the progress of the attack it gradually converges round the threatened point, there will probably only be room for part of the guns in the more forward position. The remainder will then

cease firing when masked, and refit and get re-supplied with ammunition ready to open again, to protect the troops falling back in case of a reverse, or to make a forward movement if the capture of some part of the enemy's position renders it possible to bring up more guns to prepare the way for a fresh advance.

The second forward position of the batteries which immediately support the infantry attack should be so chosen that the guns may be able to fire on the point of attack until the infantry reaches its last halting place previous to the final rush. Hoffbauer gives as an average distance from the enemy's position from 700 to 800 yards. He says that the tables in the Prussian musketry regulations give 650 metres as the extreme range at which good musketry shots can with certainty hit a broad target the height of a man. Beyond that distance he says artillery can work. We are not likely to meet troops who shoot better than the Prussians, so what their artillery can do ours will also be able to do. And Hoffbauer considers the close support of artillery to an infantry attack as so important that he says, "The question to be asked is not, 'Can the artillery not give the support from a position further back, which it is possible for it to give from a position further forwards?' The question must much rather go, 'Cannot the artillery afford that support from a position further forwards, which it is now affording from a favourable position further back?'" *

From the first position of the artillery the fire should be cool and deliberate, directed first on the defenders' artillery, next upon the point of attack.

From the second position the point of attack should be the principal object of fire. The enemy's batteries should be neglected if they fire only on the attacking artillery, but they must be kept in check if they direct effective fire on the attacking infantry. When the infantry have advanced so far that the point of attack can no longer be fired at, then fire must be directed on any reserves that may be visible, and the batteries must be prepared to resist counter attacks.

When a flank attack is intended it is not desirable that batteries should at once be sent round with the outer wing of the turning force. In the first place, sending artillery early round indicates the approaching attack to the enemy; and, secondly, by keeping the artillery on the pivot flank it has the opportunity of enfilading a retired flank of the enemy's line, and the principle is adhered to of keeping the artillery massed for the decisive preparatory action. Later on, when the flank attack is developed, batteries may be sent round to the outer wing with advantage, because of the opportunity thus afforded of getting a cross fire on the enemy's position, and of the moral effect of artillery approaching the line of retreat of the defending force.

* Hoffbauer, Tactik der Feld Artillerie, p. 57. The evidence of Todleben may be also cited as to the importance of continuous and close support of infantry by artillery. See the passage from his "Siege of Sebastopol," quoted in Home's Precis of Modern Tactics, p. 128.

As regards *cavalry*, it is impossible to lay down any detailed rules for its employment in battle, the general duties that may be expected of it have already been touched upon.

Engineers should accompany an infantry attack when possible, in order to prepare positions that have been gained as quickly as may be against counter attacks.

Defence.

There are, speaking generally, two natures of defensive battles, one when a General hopes by accepting battle in a favourable position so to break his enemy's strength as to be eventually able to obtain decisive success by taking the offensive, and the other when some important point or operation is to be covered.

In the first case a General has a certain liberty of movement, so that if the enemy does not attack him in his chosen position, but tries to manœuvre him out of it, he can either advance to the attack himself or retreat without compromising his army or the object of his operations. He can, therefore, select a position favourable in other respects, so situated as to render it probable that the enemy may be obliged to attack him, and *suitable in extent to the number of troops he has available.*

In the second case a General will gain his object if he only succeeds in holding his ground, but he cannot retreat or permit the enemy to get past him without giving up the object of his operations. He must, therefore (supposing he is unable to anticipate the enemy's movements by attacking himself), guard all the routes by which the enemy can advance, and *may have to extend his troops over a much greater extent of ground than would be generally advisable.*

It may also happen sometimes that a battle is fought under a combination of these circumstances, *e.g.*, the battle of Waterloo, where the Duke of Wellington's object was both to cover Brussels and to obtain a decisive victory over Napoleon.

To consider first the case when a decisive result is to be aimed at.

When a General decides that he will accept battle in a defensive position the first thing he has to do is to select his position. The following are the principal points that have to be considered in making a selection. In the first place the extent of the position should be proportionate to the strength of the force that is to occupy it. Inasmuch as mere passive defence will seldom lead to decisive results, the object aimed at by fighting a defensive battle will be to make the assailant exhaust his strength in fruitless attacks, so that in the end the defending force may in turn take the offensive and change a mere repulse of the enemy into a decisive defeat. In order to obtain this object a part only of the defensive force should be employed in the first part of the action, the passive defence, so that the remainder may be available to take the offensive when the favourable moment arrives. Therefore the extent of the position should be confined within such limits that its passive defence may be carried out with a

part only (from a half to three-fourths) of the whole force There is, however, an advantage in extending the position to the utmost extent possible, consistent with the above condition, for the following reason:—The enemy, in consequence of the frontal strengh of a position, under modern conditions will be very apt to try and turn one or both flanks of a position. If the front, then, is of small extent, a comparatively small part of the attacking army will suffice to act against it, leaving a large part available for the turning movement, so dangerous to the defence; whereas, if the front be broad, as the assailant must keep the defenders employed along the whole of it, but a small proportion will be available to act against the flanks. Carrying this consideration a little further it will appear that the strength of the attacking force should be taken into consideration to a certain degree in determining the extent of ground the defenders should occupy, for the stronger the attacking force the greater should be the extent of ground that he should be obliged to attack frontally so that the strength of the force he can use for turning movements may be diminished as much as possible. A small force can safely occupy a greater space in proportion than a large one, because the commander can overlook the whole field, and one reserve in a central position will suffice, whereas in the case of large forces the commander will not be able personally to superintend the whole field, and two or more large reserves must be formed to be at the disposal of the officers to whom may be entrusted certain portions of the line of battle. For a small force under 20,000 men, 6,000 to 10,000 men per mile of front might suffice to adequately occupy the position. In the case of large forces, 15,000 men per mile would seem to be a fair average proportion of troops to ground.

It will, however, not usually be the case that a position can be found exactly fitting the number of men available, but the above considerations will give a basis for selecting the nearest approach that can be found to what would be theoretically advisable, and the General must then occupy it in the best way he can with the troops he possesses.

The other points that have to be taken into consideration in selecting a position are the following:—In the first place, as regards the ground within the position itself. There should be sufficient depth for the posting of reserves and moving them from one part of the position to another, with good communications parallel to and behind the front. The flanks should be strong, either by nature, or art, on account of the modern tendency to outflanking movements. There should, besides, be good points of observation, from which the enemy's movements may be scanned, and there should be no ground unseen that the enemy can advance over. There should be open ground in front of the position at least to the limits of the range of effective musketry fire. The main line should be as even as possible, without any marked salient points; the latter, should they occur, will be weak points, because of the chance they offer to the enemy of bringing con-

verging and cross fire to bear on them, so as to render them untenable, even before the assault of the infantry takes place. Especially are woods dangerous that stretch from the position to ground that may be reached by the enemy, for they enable him to creep up under cover into the heart of the position. There should also be facilities in some one or more portions of the position for delivering counter-attacks.

The most favourable sort of position appears to be the crest of a broad ridge, gently sloping towards the enemy, and with the reverse slope not too steep to allow troops to move freely on it, and open. In this case there is good cover for the reserves, the troops in front line may be well protected without works of high relief, which will attract the enemy's notice and give him good objects to aim at, and the ground over which he will have to advance will be most effectively swept by fire. Villages, coppices, &c., in the line of battle must be strongly occupied and held, as they will infallibly attract to themselves the enemy's attack, but it is doubtful whether they give as much strength now as formerly, for they afford an excellent mark to the enemy's artillery, which, if it concentrates its fire upon them, can hardly fail to render them untenable, whereas mere lines of trenches on an open crest of a hill give but a poor object to aim at. Positions should not be chosen in which there are villages, woods, &c., within range of the position, but which cannot be included in the main line of defence. With respect to very steep ground, it may be said that it gives to the defenders certain advantages at the price of other disadvantages. Its disadvantages are that in most cases the slopes cannot be effectively seen from the defenders' shelter trenches unless the latter are actually on the face of the slope when they are much exposed to the attacking artillery. On the other hand, if the main line of defence is a little way back from the edge of the heights, the attacking infantry will mask its own artillery when it reaches the plateau, and it will be very difficult for the latter to obtain a forward position from which it can continue to support its infantry, as it will, in order to do so, have to mount the heights and come within the effective fire of the infantry in the defenders' line on the high ground. The truth of this was clearly seen both in the battle of Woerth and in that of Spicheren.

As regards the ground on which the enemy will have to deploy his forces for the attack, it is an advantage to the defenders if it is intersected and cut up by woods or obstacles that will hinder the development of his artillery, and if the lateral communications are few and bad, especially if some impassable obstacle divides portions of his front.

It will of course very seldom be the case that a position can be found that will combine all these advantages. All that can be done is to choose that which has most advantages and fewest disadvantages, bearing in mind that the most important points are protection for the flanks, open ground in front, good lateral communications, and cover for the reserves.

Let us now suppose that the position has been selected, the next

point is how to arrange the troops to defend it. As has already been stated, a part of the force, from quarter to half, should be kept in reserve to meet unexpected movements of the enemy and for the decisive counterstroke. To the remainder of the force the defence of the position will be entrusted: the whole front will be divided into sections, to which definite bodies of troops will be assigned. Then the commanders of each of these bodies of troops will proceed to distribute his troops in the section assigned to him.

In the first place, the position for the batteries will be selected. It will depend upon the circumstances of each individual case whether each commander of a section of the defence will arrange his own batteries, or whether the whole shall be placed according to a scheme emanating from superior authority. In any case, the bodies of troops forming the reserve will keep with them the batteries belonging to them, but positions in the first line should be assigned to all the batteries belonging to the troops to whom the defensive task is entrusted, although it does not necessarily follow that they should all occupy these positions at the very commencement of the action.

The following conditions will influence the selection of the positions for the batteries. The objects that the artillery of the defence should have in view are to force the assailant into deploying his forces and showing his intentions as soon as possible—to prevent him from establishing a superiority of artillery fire and preparing the way for the advance of his infantry—and to shake and destroy to the utmost the attacking infantry when it advances. To gain these objects the artillery should be able from its position to command as far as possible the roads by which the enemy must advance, and the ground on which he must deploy when he can no longer keep to the roads; it should also be able to bring a large amount of fire to bear on the ground on which it is probable that the attacking artillery will deploy, and finally be able to sweep the whole of the ground immediately in front of the main position over which the infantry attacks must be made.

If these objects can be obtained from positions within the infantry position it will be so much the better, as the batteries will be less exposed to musketry fire. Such was the case with the German artillery at the battles on the Lisaine, Jan. 1871. But cases will occur when from within the infantry line either the ground within artillery range cannot be all seen, or the ground on which the enemy will deploy cannot be effectively reached. In such cases it will be often desirable to push the batteries forward in the early part of the action, as the German I. Corps did at the battle of Noisseville, drawing them back when the attacking infantry endangers their safety to positions prepared for them within the infantry position, whence they can carry out the last part of their task, the co-operation in the close defence. As in the attack, massing the guns will conduce to unity of action, but is perhaps less essential.

When the positions for the batteries have been chosen, the infantry will be placed in position. At first, before the enemy's in-

tentions have developed themselves, the position will only be occupied in skeleton, a few troops being placed only in certain important points, and the remainder kept in hand until wanted. When, however, it becomes evident that the enemy is going to attack any part of the line, the troops in each section threatened should be arranged in two lines and a reserve. With small forces, when the extent of a section is small, the second line and reserve may be merged in one, but in an extensive position each section should have its reserves independent of the main reserve.

The first line will consist of a line of men under natural or artificial cover, as close together as they can be, with freedom to use their arms, *i.e.*, about one man per yard, and of supports to make good casualties. It will usually be sufficient if these supports are half the strength of the firing line. The second line will consist of bodies kept together under cover in such positions as to enable them to aid in the defence of important points at critical moments by counter attacks, or to repair the mischief if the enemy has succeeded in breaking through the first line at any point.

It will not usually be necessary to occupy the whole front of a position in equal strength ; there will usually be strong points on which the enemy will be sure to direct his attacks, and while these must be strongly occupied, the ground between them need only be watched by small bodies of troops further back. This task will usually be fulfilled by troops of the second line.

Should there, unfortunately, be in the position a weak point, such as a wood stretching from the position on to the enemy's ground, there will be nothing for it but for the General to place in it his best troops with instructions to die there if need be, but, at all hazards, to keep the enemy from penetrating through it further than a certain point, where if a belt can be cut down, so much the better.

We then have arrived at this. The Commander-in-Chief will retain what main reserves he thinks fit, and will entrust the defence of the positions in sections to the remainder. Of these latter, a force sufficient to give from one and a half to two men per yard of the front actually to be occupied will be placed in first line, and the rest divided between second line and reserve according to the discretion of the commanders of the section. It will often be desirable to push forward a certain number of men as skirmishers from parts of the position where masses of artillery are placed, in order to keep the enemy's tirailleurs from annoying the batteries, and also towards the positions where the hostile batteries are likely to be deployed to keep them at a distance, but these skirmishers should clear the front as soon as the serious infantry attack it developed so as not to mask the fire of the main line.

The cavalry will probably be employed in watching the flanks, and seeking opportunities of molesting the enemy's march, or else will be kept in reserve in rear of the whole.

It is not within the scope of this paper to discuss the question of

the entrenchment of a position, which has been most ably done by Captain Fraser, R.E., in his Royal Engineer Prize Essay.

The question of the position of the reserves is of some importance. The loss of the battle of Gravelotte by the French may be attributed, in some degree, at all events, to the fact that Bazaine, fearing quite unnecessarily for his left flank and communications with Metz, kept his reserves on the plateau of Flappeville in rear of his left, and only sent aid to Canrobert, on the right, too late to save St. Privat, and the consequent compromising of the whole of the French position. Two considerations influence the posting of the reserves; in the first place they should be within reach of the points on which the enemy's chief attacks are likely to be directed, and in the second place they should be favourably placed for making offensive counterstrokes. They may either be kept in one mass, or divided into several parts as will best fulfil these conditions. If there is reason to expect a serious attempt of the enemy to turn a flank of the position, the best way to meet it would appear to be by troops placed ready in echelon behind the threatened flank in such a way as to take the flank attack itself in flank. The body of troops intended to guard against the turning movement may even be stationed at some distance from the extremity of the position, so as to be in a situation to come up in rear of the enemy's turning movement. The Duke of Wellington at Waterloo had Chasse's Division in such a position at Braine l'Alleud during the early part of the battle. If a body of troops be thus detached it may be connected with head-quarters by field-telegraph, as Colonel Hamley suggests.*

Let us now consider the method in which a defensive action will be carried on. During the first stage, that of the reconnaissance of the position by the enemy, the defenders should not be tempted to show more of their force and dispositions than is necessary. The enemy's attacks must, of course, be warded off, but only so much infantry and artillery should be shewn as will suffice for this. It will not generally be possible to prevent the enemy from obtaining a more or less exact idea of the nature and extent of the position occupied, but he need not be allowed to find out the position of more guns than are absolutely required to keep in check those which he brings up, or to discover the position of the reserves

As soon, however, as the enemy begins to show signs of preparing for serious attack by developing large masses of artillery, then all the batteries of defence (except those with the reserve) should occupy themselves with trying to prevent the obtaining of a superiority of fire by the attack.

That there will be an artillery duel at the commencement of a battle is therefore exceedingly probable. The artillery of the attack must silence more or less completely the artillery of the defence, or no attack can be made with any prospect of success, and until this is done it will not be able to direct its fire on the infantry line of the

* Operations of War, 3rd Ed., p. 437.

defence to prepare the way for its own infantry, under pain of being itself silenced. On the other hand, if the artillery of the defence does not engage the attacking artillery, the latter can accomplish its task unmolested, and, further, at the commencement of an action, in all probability, but little will show itself on the assailant's side except artillery. As soon, however, as the assailant's infantry begins to show itself in sufficient force to present a good object to fire at, the defensive artillery should, without doubt, direct a part at least of their fire at it, as the grand object of the whole fighting is to beat the infantry. At later stages of the action, in fact, the artillery of the defence should direct its *whole* attention to the attacking infantry.

The artillery of the defence in this artillery duel will have an advantage in being, in all probability, protected by entrenchments, and in having had the opportunity of measuring beforehand the ranges to all points where the artillery of the attack is likely to place itself. With the aid of these advantages it is possible that the defence may maintain a superiority of fire. If this be the case, it will be hardly possible for a direct attack to succeed. But in all probability, inasmuch as the assailant can choose the point where he will attack and bring up large masses of artillery to bear upon that point, he will eventually obtain a superiority over the artillery of the defence, and will begin to direct part of his fire upon the part of the main defensive line where his infantry attack is to be delivered. After this artillery preparation, the infantry attack will begin.

When the infantry attack begins the artillery of the defence will direct its principal attention to repelling it. No definite rule can be laid down as to the objects of its fire, whether firing line, supports, or reserves ; any of these may be the object at various times. If masses of infantry should, however, at any time show themselves, they will afford a better mark than thin lines of men at open order.

When it becomes evidently no longer possible to cope with the attacking artillery successfully, it will be for the superior authorities to decide whether any of the batteries should be withdrawn temporarily from action, in order that they may be kept in readiness to come forward again later in the action when the assault is immediately threatened, to aid the infantry in the final struggle. This will probably only be necessary if the batteries run the risk of being entirely disabled if they remain in action, and when the artillery that was in reserve has been employed elsewhere, so that if some batteries were not withdrawn for a time there would be no artillery to take part in the fight at the critical period.

When the infantry attack develops itself, the skirmishers that were originally sent out to keep the enemy's tirailleurs from annoying the guns of the defence and to keep at as great distance as possible the attacking batteries, should fall back and clear the front so that the fire of the main line, which should now be fully occupied, may be unimpeded The defenders should remain in their covered position as long as the enemy is kept at a respectful distance, for to advance will give up the advantage of cover without any corresponding gain, for

the action has not yet reached the stage of decisive counterstroke. Should, however, the enemy succeed in approaching within dangerous proximity, so that an assault on an important point may be expected, portions of the troops in second line should be brought up in order by counter-attack at favourable opportunities, to ward off the threatened danger. These counterstrokes will be delivered with most effect on the flanks of the troops assailing any point, and their judicious timing will be a matter of good judgment. If delivered too soon the enemy may be able to repulse them, and if not soon enough it may be too late to save the post. When the enemy has approached within rushing distance of the point of attack, the troops destined to make the counterstroke should be brought up in close proximity to the threatened point and formed ready for immediate advance, but still kept, if possible, under cover. Then a forward movement, just as the assailants are disordered by their rush to the assault, will very probably be crowned with success. The troops occupying the main line of defence should, as a rule, not take part in this counter-attack, but remain prepared for any return movement on the part of the more rearward lines of the attackers. In this manner the fight will be continued, the action wavering backwards and forwards until the strength of one side or other is exhausted. Reinforcements, if need be, must be sent to the defensive line from the reserves, but the latter should be kept intact as long as possible for the decisive counterstrokes.

When, where, and how to deliver these decisive counterstrokes is the most difficult problem for a General acting on the defensive to decide. In former days, when battles were usually fought on open plains, with the two armies drawn up within view of one another at no great distance apart, a General could see if his adversary made any mistake and gave him an opportunity of striking; but in these days, it will be very difficult for a General on the defensive to know whether the assailant has exhausted his strength at any point so that a counter-attack will have a fair chance of success, and he will be liable to let the favourable time pass by, in fear lest he should be drawn from his strong position and use up his reserves whilst his enemy has still troops in hand to repel his attack and punish him for his false move. In making a right decision under these circumstances a General will have full scope for showing his discernment and genius, and it is impossible to give any definite rules by which he may be guided. One consideration may, however, be mentioned, which might give a clue to a right judgment. If an attack which is evidently a real one and has been pressed on with vigour and determination, continually strengthened by fresh troops from time to time, begins to slacken in its intensity, it is a fair deduction that there are no more reserves immediately available on that part of the field, for it is a maxim that serious attacks once begun should not be allowed to wane, but should be continuously pushed on to the end. Therefore, a General commanding on any part of a field of battle finding an important attack slackening, will probably find himself in presence of an oppor-

tunity when he should (if consonant with the general plan of the battle) send forward his own immediate reserves to change the enemy's cessation of advance to a retrograde movement, and send word at once to the Commander in-Chief, that he may be able to take further measures to reap full benefit from the new aspect of affairs. In so acting, however, care must be taken, and careful judgment exercised not to be deceived by ruses on the part of the enemy.

In this way will the direct attacks be met. Flank attacks will be direct on the flank assailed, and will be met in the same way by the troops occupying that flank, and ought moreover to be attacked in flank and rear by the troops placed for that purpose, as already pointed out.

The action of the artillery will be that already sketched out, at first to force the enemy to deploy and to endeavour to prevent his establishing a superiority in artillery fire, and later, to use all its efforts to aid its own infantry to ward off the infantry attacks. In performing the latter task, its last positions should be such as to sweep, if possible with cross fire, all the ground in front of the points of attack, and batteries kept in reserve from the beginning for the purpose, or withdrawn from the action at an earlier period, should be brought up when assault is expected, and should fight to the last, regardless of losses or of coming under infantry fire, to co-operate with the infantry when the assault is actually delivered.

The cavalry will watch the flanks so as to give timely notice of turning movements. They may also, by excursions into the rear of the attacking army, try to create confusion and delay among the ammunition and other trains, and any cavalry not so employed, will be held in reserve to complete the defeat of repulsed troops, or, at critical moments, to sacrifice themselves in desperate charges to gain *time* for expected reinforcements to arrive.

The engineers will, of course, have their occupation in works for the strengthening of the position, and perhaps in laying and working telegraphs to and from different parts of the battle field or signal stations.

Finally, with regard to the employment of the reserves. They should be kept intact as long as possible for decisive counterstrokes, as already touched upon, but yet no important point of the defensive line should be permitted to be lost for want of timely aid. A General's powers will be shewn in the management of his reserves, so as not to be too late in sending reinforcements, while not using them unnecessarily early. If an important point in the defensive line should unfortunately be captured, strong efforts should be made to re-take it before the enemy has time to settle himself in it. Even if the recapture is not effected, such a course of action will reduce him to the defensive at that point, and the battle may be won elsewhere. Troops should, however, not be wasted in costly efforts to re-take positions in front of the main line that may have been captured, but whose loss does not necessarily endanger the position.

With respect to the artillery with the reserve, the General must

decide, according to the circumstances of the case, whether he will employ it to reinforce or replace batteries in the defensive line, or keep it in reserve till the counterstroke is to be delivered to prepare the way for it. If the counterstroke can be prepared for from positions in the front line, it would be probably best to send the batteries into that line, so as to reduce the danger of its being forced; but, if the counterstroke is to be a wide one, then batteries might probably be with advantage kept with the troops who are to make it.

A word may be said with reference to advanced posts. It is not desirable to have posts strongly garrisoned beyond the reach of support from the main line, as it will not be possible to hold them permanently, and loss and discouragement will follow their abandonment after a period of stubborn defence. Strong points, however, immediately in front of parts of the main line, if they are capable of defence to the end, may sometimes prove advantageous, for instance, in rendering it difficult to turn a flank, as Hougoumont at Waterloo. Of course an army in position will always be protected by outposts, and positions considerably in advance of the main line may be sometimes temporarily held with advantage to hinder the deployment of the enemy's artillery, if he tries to push it forward without adequate support; but they should be given up before the troops occupying them become compromised by the advance of the hostile infantry in force.

With regard to the second class of defensive battles, viz., *covering actions*, they differ from those already discussed in that the defender's main object is merely to maintain his position, so as to prevent the enemy from getting through. The same principles as have been already laid down for defence will apply to covering actions also, but as the line may very probably have to be very weakly held, no pains should be spared in strengthening the front of the position. If the enemy can only advance at certain points, at those points should the strength of the defenders be concentrated, and the utmost vigilance must be exercised to obtain the earliest information of the direction of the enemy's advance. Reserves are required in this case even more than in the other, to be kept in hand to reinforce the most dangerously threatened points, and the communications between parts of the position are most important. What may be done with very small means for the defence against greatly superior forces of an extensive position is well shown in the battles of the Lisaine in January, 1871.

Explanation of the Plate.*

The plate is intended to illustrate the arrangements which might be made for the defence and attack of a position by small forces organised as in the British Army.

It is supposed that a blue division, reinforced by two batteries of the Corps Artillery, has been detached to cover the passages of the Thames by the road and railway bridges near Streatley, from a rather

* The plate has been reduced from the military 6 in. map, and the arrangement of the troops has been made according to the indications of the map, without personal acquaintance with the ground.

superior red force, which is advancing from the south on Standford and Bradfield. The commander of the blue force decides to take up a position near Basildon Green. In this position he will directly guard the shortest roads to the bridges he has to protect, and if the enemy attempts to pass round his flank either by Aldworth or Pangbourne (where the bridge is supposed to be broken), he will be favourably placed to attack the enemy whilst engaged in his flank march.

The first point the blue General will have to decide after he has settled upon his field of battle, is the extent of ground he will occupy. It will be observed that on the right flank, the wood near the brickyard, with Driftwood in echelon behind it, mark out pretty clearly the right of the main position; while the left is placed where the crest of the high ground sweeps round to the north above Basildon Green. The extent of the front is about 1,500 yards, which may be well held by the 9000 men of the division.

The next point is the arrangement of the troops in the position.

First, the situations for the batteries have to be chosen. Of these one is to be kept at the beginning in reserve, and the rest placed in the position. Looking at the ground the enemy will have to advance over, it will be seen that the most favourable ground for him to bring up his batteries is at Ashampstead Common, and on the open ground about Blackwell Farm and Buckle Row. Accordingly the batteries of the defence must command those points. They must also be able to sweep the ground over which the attacking infantry will move. These conditions will be fulfilled to a great degree by the batteries being placed as in the plate. Most of the guns command both Ashampstead Common and the Buckle Row plateau, and the ground in front of the position is swept as far as possible, to a great extent by cross-fire. Next with respect to the infantry. The General decides to entrust the defence of the position from Kiln Farm to the right to the 1st brigade, and from that point to the left to the second brigade, keeping back a battalion from each brigade and the divisional battalion as a reserve.

Then the officer commanding the first brigade having two battalions to dispose of, places two companies in Kiln Farm, one in the brickyard, and one in the corner of the wood near it. The remaining four companies of this battalion are retained in second line. Of the other battalion two companies are sent to Quick Green, which is to be held as an advanced post, being flanked by the guns behind it; a third company is told off as escort to the battery on the flank, and the remaining five companies are kept in second line at Driftwood.

The officer commanding the second brigade places two companies in Basildon Green as an advanced post, and two more in the main position behind, keeping the remaining four companies of this battalion under cover in a hollow further back. The second battalion is kept intact as a reserve at Upper Basildon.

The three battalions and battery of the main reserve are kept well covered in rear of Upper Basildon.

Thus at first the position is only occupied in skeleton, until the

enemy developes his attack; but troops are ready continually to strengthen parts of the front that may require it, or make offensive returns.

It will be observed that the right of the position is refused, and, moreover, strong in the support of the buildings at Driftwood; therefore the left has been especially regarded in the disposition of the troops. The 2nd brigade has less front to guard than the 1st, and can therefore keep a whole battalion in reserve, and the main reserve is so placed as to be able to assist the left in the shortest possible time.

As regards artificial strengthening of the position, the amount to be done will depend on the time available. Emplacements will, however, certainly be made for the guns, and shelter trenches for the infantry, wherever they have no natural cover. The woods at Quick Green and in front of it should also be cut down, and made into entanglements, and the buildings placed in a state of defence, as far as time will allow.

The question of occupying the buildings in front of Basildon Green was considered, but they are small and much exposed; so it was deemed best to leave them unoccupied. If time permitted, they should be destroyed.

The cavalry watch the flanks of the position.

Attack.

We now turn to the attacking force. It consists of a division complete, with an infantry brigade, and three batteries from the Corps Artillery in addition. The division is marching along the road Y through Bradfield; the additional brigade and the three batteries from the Corps Artillery along the road X through Standford. Each column has two squadrons of cavalry pushed well in advance, followed by an advanced guard, consisting of a battalion and a battery. The cavalry will first come upon the enemy, but will not be able to find out much, as it is but weak. The advanced guards will then bring up their batteries on to Ashampstead Common and the Buckle Row plateau, and with their aid the infantry will be able to discover that Quick Green, Kiln Farm, and Basildon Green are occupied by the enemy.

During the advanced guard action, the General has been reconnoitring and considering his plans. The front seems very strong, he therefore determines to direct his main attack on the defender's left flank at Basildon Green, as that flank is the most exposed and artillery on Ashampstead Common will be able to enfilade the enemy's line if he throws it back to meet the flank attack. At the same time the brigade on the road X is ordered to attack the enemy's right to divert his attention, and to take advantage of the opportunity if the enemy weakens his right to strengthen his left. A demonstration is also to be made against the front of the position.

To prepare the way, the batteries are brought up on Ashampstead

Common and the Buckle Row plateau. The advanced guards protect the batteries, and the deployment of the rest of the troops. The batteries try to silence such guns of the defence as show themselves, and direct as much fire as can be spared from this object on the strong points visible in the position and the points which must first be assailed, *i e.*, Quick Green and Basildon Green.

The General keeps the 2nd brigade of the division marching on road Y in reserve, and the 1st brigade of that division and the brigade on road X advance to the attack. Each of these brigades keeps one battalion in second line, and sends two forward in first line. The battalions in first line form according to the method laid down in the appendix to G.O. already alluded to.

The divisional battalion is ordered to advance in the centre with its two half battalions alongside one another to connect the wings of the attack, to cover the guns, to annoy the hostile batteries with the fire of skirmishers, and to keep the enemy fast by demonstrations; but it is not anticipated that it will be able to carry through a serious attack.

The cavalry guards the flanks of the attack.

The attack is carried out according to the principles laid down in the body of this paper. As the 1st brigade advances, some of the batteries may be sent round to its right flank to co-operate more effectively in the attack.

In reality, the situation of the troops could never be so regular as is shown in the plate. Probably the battalions of the advanced guard would have remained engaged with the enemy, and not have been reformed in their brigades before the regular attack commenced. The second battalions of the brigades would, in that case, be sent to their assistance in the direction most suitable to the existing circumstances. The battalions also in first line would have been obliged to extend more, and bring up some of their supports before they got so near the enemy as is shewn in the plate. All that has been aimed at in the Plate is to show the general arrangement of the troops for the commencement of the attack. The details would have to be varied, in reality, according to the varying features of the struggle.

In conclusion, the writer desires to express his grateful acknowledgments to Captain F. Roberts, R.A., for the great assistance he has rendered him in preparing the plate that accompanies the paper.

ON.

REFERENCES.

Cavalry		
Artillery		
Infantry	Battalion	
d.°	Half d.°	
d.°	Company	
d.°	d.° partly extended	
Wood		
d.°	cut down	

N.B. *Contours are at 50 feet vertical intervals their altitudes being measured above M.S.L.*

Maclure & Macdonald, Lith. London

ATTACK AND DEFENCE OF A POSITION.

REFERENCES.

- Cavalry
- Artillery
- Infantry Battalion
- d.° Half d.°
- d.° Company
- d.° d.° partly extended
- Wood
- d.° cut down

N.B. Contours are at 50 feet vertical intervals their altitudes being measured above M.S.L.

Vincent & Macdonald Lith. London.

RAISING 38-TON GUN FROM MUD.

DIARY OF OPERATIONS,

BY

CAPTAIN H. SOAMES, R.A.

At Cliffe Fort, on Monday, 14th May, 1877, the barge "Magog," landed the gun on to a railway, which subsided, and deposited the gun in mud.

On Tuesday, 22nd, Captain Soames and 40 men arrived from Sheerness, to assist the detachment who were at Cliffe, under Lieut. Knight, R.A., to raise it.

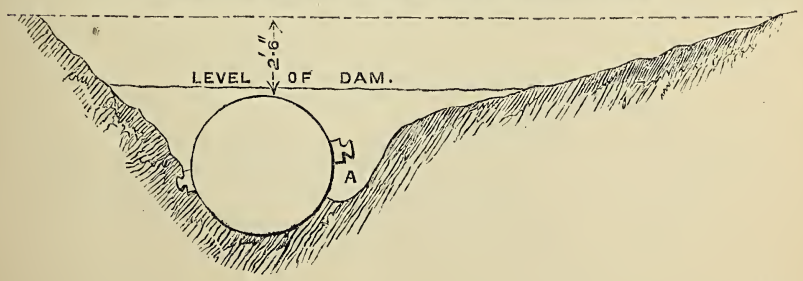
On Wednesday, 23rd, the gun was lying about 3′ from the remains of the tramway; the upper surface of the gun being about 2′ below the surface of the mud.

The mud had been dug away on one side, and the ground sloped towards a tramway which lay parallel to the gun, and about 25 yds. from it.

The left trunnion was much the higher; but in consequence of a hole having been dug under the right trunnion, in the hopes of

Fig. 1.

LEVEL OF SALTINGS, ORDINARY SPRING TIDE.



passing a parbuckle rope under the gun, the gun was revolving slowly on its axis.*

At this time the gun was covered by the tide at high water, till the neap tides on the 22nd were kept out by a small dam, some 2′ thick, of mud thrown up from the pit.

It was now considered impossible to dig holes deep enough and numerous enough under the gun for parbuckle skids, because the gun rolled into even the small hole, *A*, cut for the parbuckle rope; in fact,

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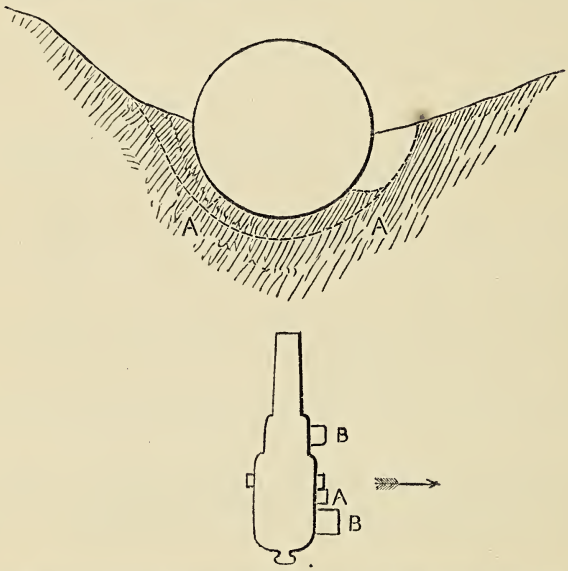
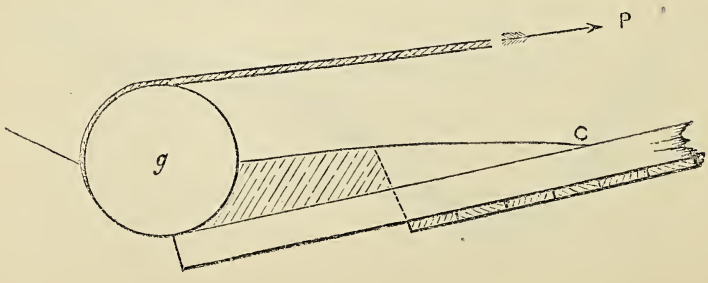
* The proposal to parbuckle the gun out of the mud involved digging holes, three in number—

1st, for parbuckle rope, all round the gun;
2nd, for breech skids, 2′ 6″ wide at least;
3rd, for muzzle skid, 1′ 3″ wide at least.

1st. This was attempted and found almost impossible, because the mud was so soft that no man could get under the gun to dig out the portion *AA*.



2nd. The gun showed already a disposition to revolve in the direction ⋙⟶, in consequence of the first hole being dug, and it was obvious that the holes *BB* would increase this tendency even if the sinking could be checked in time.



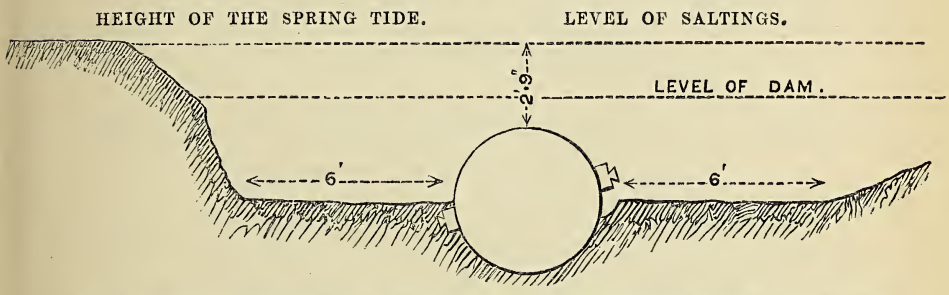
the mud was so liquid that any depression filled itself up, and the men had to work (digging) nearly up to their middles.

Thursday and Friday, 24th and 25th May.

The high tides came higher, and the sea leaked through the dam. A sea wall had therefore to be built, in anticipation of a spring tide, on Tuesday, 29th, to close the estuary, which ran up to the gun pit. The men were working from 9–12 and 2–4, and it was decided to work by reliefs, 8–10, 10–12, 12–2, 2–4, as the fatigue of throwing up the heavy wet mud was very great. The water was kept out, and the wall completed by continuous labour, on Tuesday 29th, keeping pace in height and thickness with the strength required by the increasing height of the spring tide.

Fig. 2.

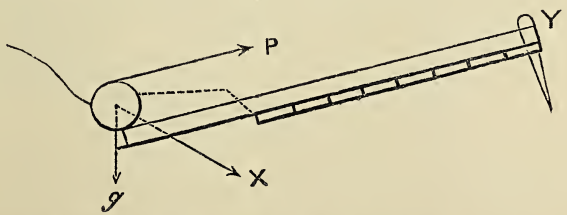
Section on *AB*.



As the gun was sinking fast, it was determined to lay down two platforms, $6' \times 10'$, parallel to the gun, and support the latter by a sabicu beam, $18' \times 12'' \times 12''$, lashed to the trunnions with 6″ rope (white.)

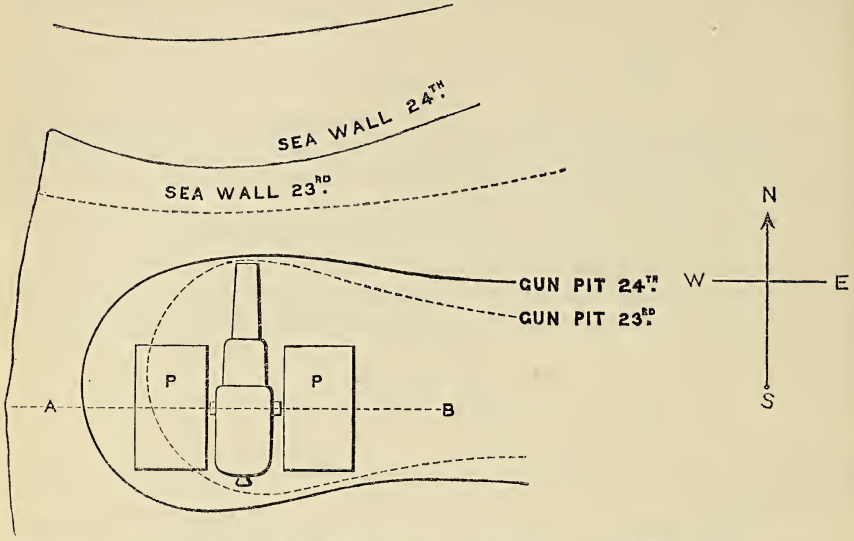
3rd. It was calculated that no trench parallel to the gun could be cut below the centre of gravity of the gun, for a transverse plank to support the parbuckle skids, nearer than *C* (about 5′ from the gun), because the mud was so very soft and wet, and had no consistency. The parbuckling power, acting in the direction *P*, would have to pull the gun over a mass of mud (shaded), also overcoming the suction of the wet bed in which the gun lay.

4th. The force of gravity and the power *P* would have had for their resultant a force, *X*, acting rather downwards at the point of support. The parbuckle skids, not being supported at this point, must have sunk; no pickets at the point *Y* could have kept them down, the mud being very soft and treacherous.



These considerations determined us to forsake the idea of parbuckling out of the mud, and it was determined to raise the gun vertically, sufficiently to place skids on platforms on both sides of the gun,

Fig. 3.



The digging was completed for the two platforms, *PP*, on the 24th.

Friday, 25th May. (*3rd day of operations.*)

The platforms, *PP*, were each constructed of—

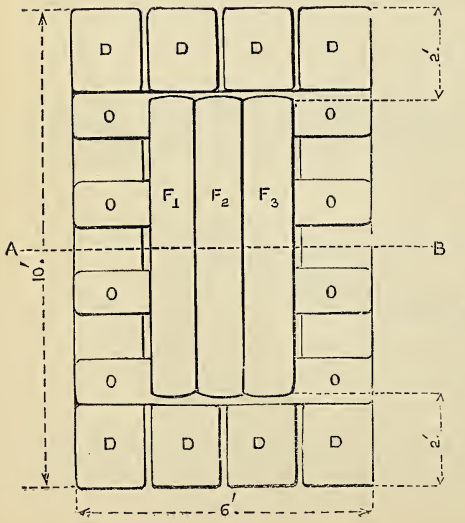
1st layer: 4 planks, deal, $10' \times 1'\,4'' \times 3''$, at intervals of 2″ apart, parallel to axis of gun.

2nd layer: 4 planks, oak, $6' \times 12'' \times 3''$, at intervals of 10″, perpendicular to axis.

3rd layer: 3 skids, fir, $6' \times 12'' \times 12''$, touching, parallel to axis.

This gave a base of 60 sq. ft. per platform, with the minimum of timber.

Fig. 4.
Plan of platforms, *PP*.



Section across *AB*.

2′ was left on either side of the 6′ × 12″ × 12″ skids, to allow the parbuckle skids to be placed (when the gun was raised) over these platforms, which were more substantial than those platforms about to be laid for the breech and muzzle.

These platforms were laid on the 25th, and levelled with a spirit level.

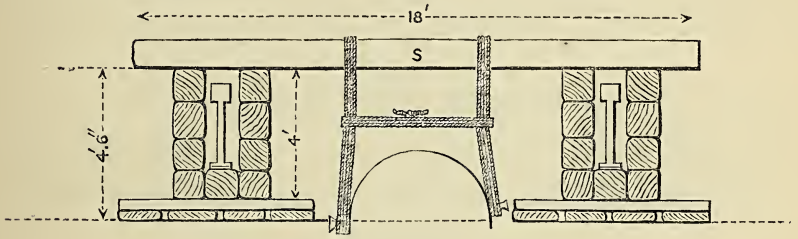
Saturday, 26th May. (*4th day.*)

In the morning the sea wall was strengthened; the gun pit was widened.

The sabicu beam had a 6′ × 12″ × 12″ skid lashed below it, and was placed over the gun, and lashed to the trunnions with 6″ rope (white) —4 returns under each trunnion. The ends of the beam were then raised by two 20-ton jacks, placed at points in the centre of the skids, F_2 (*vide* Fig. 4), and the beam was left supported by two columns of 4′ × 12″ × 12″ skids at each end. These columns rested on F_1F_3 (Fig. 4). The 6′ × 12″ × 12″ skid lashed under the sabicu beam was afterwards found unnecessary, and was discontinued.

Fig. 5.

Section perpendicular to Axis, across Trunnions.



The platforms could not be laid lower, because the gun sank into any excavation made below its centre of gravity. The sabicu beam could not be lashed lower, because jacks are 2′ 7″ high.

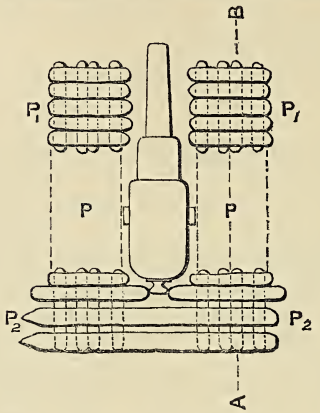
Two columns were found necessary for each end of the sabicu beam, because the platforms subsided during Saturday, Sunday, and Monday; and they were kept level by putting the weight, when necessary, on the outer or inner column, which soon restored the level of the platform. This arrangement prevented the gun from sinking after the 26th May, at which time it was 3′ clear below the surface of the mud.

Monday, 28th May. (*5th day*).

The sea wall was raised and thickened, the pit extended, and two platforms, P_1P_1 and P_2P_2, laid at both breech and muzzle; the centres being opposite to the cascable button and half-weight mark. All the planks being used in former platforms, railway sleepers, 7′ × 14″ × 3″, were taken, also 4 planks, 10′ × 12″ × 3″, and 2 deal piles, 19′ × 9″ × 9″.

Fig. 6.

Plan of Muzzle (P_1) and Breech (P_2) Platforms.



The 10′ planks and 7′ sleepers for P_2 were laid 2-deep, to bring them level with the 19′ piles, which were 9″ square. Across these platforms were laid 4 sleepers on each, the two centre ones touching. Above these were laid two 6′ × 12″ × 12″ skids, 18″ apart, perpendicular to axis of gun, and on these, parallel to them, 2 fir sleepers, to raise the columns of skids sufficiently high to allow of long skids, 12″ × 12″, to be easily placed under the cascable button and chase, as soon as the gun should come up, resting on P_1P_1 and P_2P_2 across their centres.

Fig. 7.

Section across AB (omitting PP, which are shown in Figs. 4 and 5).

Tuesday, 29th May. (*6th day*).

Two sabicu beams demanded from Woolwich not having arrived, it was determined to test the platforms. The sea wall was increased to 2′ above high water mark, and 8′ thick at high water mark, and rammed and faced with stones. The two temporary fir beams employed on P_1P_1 and P_2P_2 were lashed to cascable button and under half-weight mark similarly to Fig. 5, and the gun slightly raised. $4\frac{1}{2}$″ white rope was used in lashing, passed 8 times under the gun at each end, and the breech beam strengthened by placing a 10′ × 12″ × 3″ oak plank on top of it. The platforms subsided badly, especially the breech, P_2P_2, so they were relaid in the afternoon and levelled.

Wednesday, 30th May. (*7th day*).

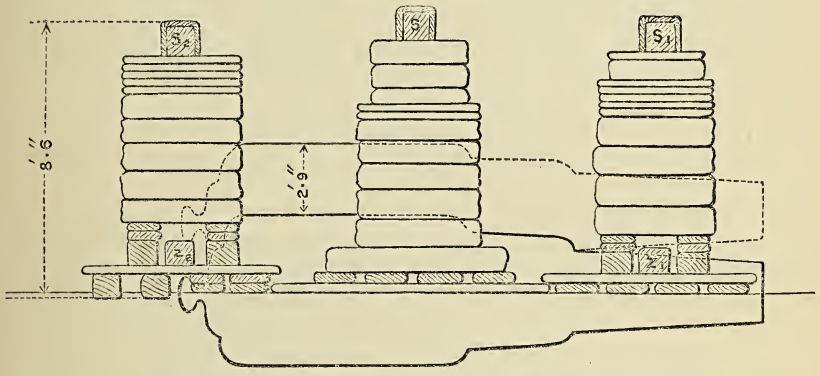
The sabicu beams arrived at 9.30 a.m., each 12′ 2″ × 12″ × 12″, and were lashed over the cascable button and half-weight mark, and the weight taken by all three sabicu beams with six 20-ton hydraulic jacks (Tangye's). The beams, at the commencement of the afternoon, were 4′ above the platforms and 4′ 6″ above the mud foundation. (*Vide* Fig. 5.)

The jacks were worked 4 at a time, the trunnion jacks going slowly always, whilst the breech jacks and muzzle jacks worked alternately. Had fewer jacks or smaller platforms been used, the columns of skids to support the beams must have got out of the perpendicular, for the platforms would not take more than 8 tons each.

On this day the men had begun to work at 6.45 a.m., and worked, except 1½ hour for meals, till 6.30 p.m., at which hour the gun was sufficiently raised to admit of long skids, $25' \times 12'' \times 12''$, being placed, one under the button of the cascable, the other under the half-weight mark, $Z_2 Z_1$.

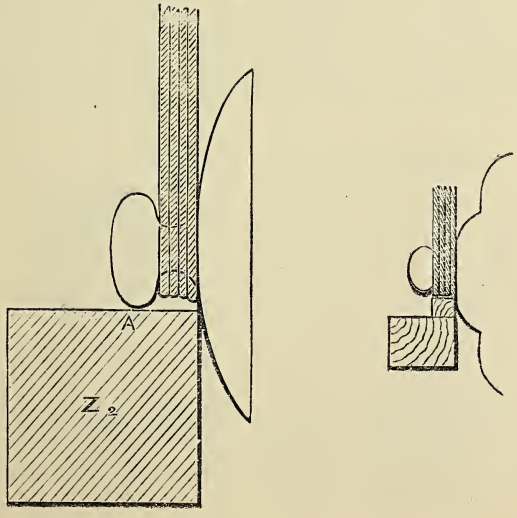
Fig. 8.

View from East.



The gun was now raised vertically 2′ 9″ from its former position, clear of the mud. The button of the cascable having a very small bearing on the $25' \times 12'' \times 12''$ skid, it was not considered safe to leave it resting thus during the night, so a further lift of 4″ was taken, and a $4'' \times 4'' \times 3'$ placed under the button at the point *A*.

Fig. 9.



A plank was also placed under the half-weight mark, to keep the gun horizontal.

Thursday, 31*st May*. (*8th day*).

In the morning, the breech and muzzle were lowered on to the transverse skids, leaving a great part of the weight of the gun on the trunnion sabicu beam, *S*. This was done to test the transverse beams, *ZZ*, under the gun, and ascertain whether, the weight being transferred to them by degrees, the centre sabicu beam, *S*, could be dispensed with and lashed lower.

The weight was now resting on the beams *ZZ*, and the centre sabicu beam *S*. It was necessary to raise the gun sufficiently high to allow of 2 parbuckle skids, $20' \times 15'' \times 15''$, resting on transverse planks 3″ thick (and over them 3″ oak planks), being placed under the breech; and under the muzzle a similar skid, with 9″ of planking on it, to bring it up to the same height above the ground.

The sabicu beams being so high above the original level of the mud, and the columns of skids so liable to tilt the platforms and overturn, the sabicu beams had to be lowered down to the gun.

The muzzle and breech beams, S_1S_2, could not be relashed at once, because the lashings were caught by the long skids, *ZZ*, which had to be placed between the $6' \times 12'' \times 12''$ which supported the jacks, in the centre of the platforms P_1P_2. They were therefore lowered by jacks, and a $6' \times 12'' \times 12''$ skid placed next to the sabicu beam, and a $3' \times 9'' \times 9''$ next. The weight was now divided between the platforms P_1P_2 and the beams *ZZ*, so as to release the centre sabicu beam, which was lashed down to the gun, by the trunnions.

The weight being taken on this centre sabicu beam, left only the preponderance to be lifted at the breech. This was done by a jack, placed so that the lip caught the cascable button.

The muzzle sabicu beam was released by having a $3' \times 4'' \times 4''$ skid placed parallel to the beam *Z*, between the lashings which held the muzzle sabicu beam. The muzzle and breech were now lowered off, leaving the weight on the centre sabicu beam and the beams *ZZ*, and the muzzle and breech sabicu beams were relashed close down to the gun.

Fig. 10.

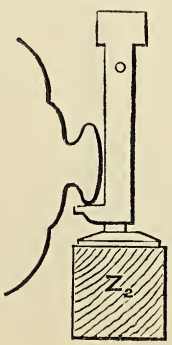
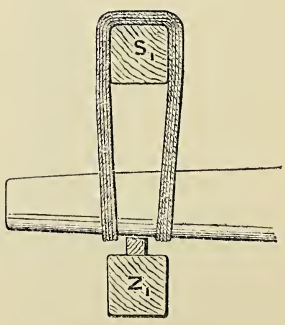


Fig. 11.



Friday, June 1st. (*9th day.*)

The three sabicu beams being now lowered, a fresh lift of 3′ was taken, and the two breech parbuckle skids and the muzzle parbuckle skids placed across the two main platforms and under the gun; the distance from the trunnion to the nearest parbuckle skid being 8″, and the muzzle parbuckle skid being placed as near the muzzle, under the centre of the short coil, as the platform *P* would permit. 9″ of planking was placed on this latter skid, and 3″ of oak planking on the breech skids.

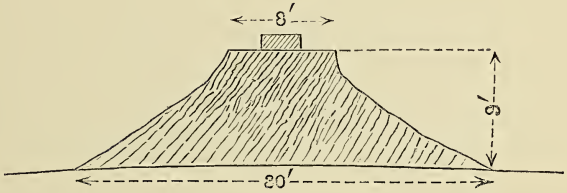
Saturday, 2nd June. (*10th day.*)

The gun was lowered on to the parbuckle skids, and the sabicu beams unlashed and taken away.

Remarks.

This operation would have been completed in 4 or 5 days, had not the detachment been obliged to contend with a rising tide, and build an enormous sea wall, 30′ long, 30′ broad at the base, and 8′ thick at a height of 9′ from the base. An additional 3′ was added to resist the disintegrating force of the small wavelets lapping against the top. Total square measure of section, 183′; total cubic feet when rammed, 5490′.

Fig. 12.



The delay in the arrival of the sabicu beams caused the loss of one day.

Average number of Men employed.

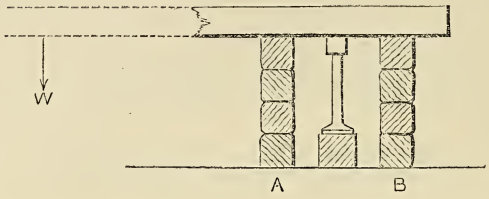
Captains	1
Subalterns	1
Staff Serjeants	2
Serjeants	2
Rank and File	40
Total	46

As soon as the digging was completed, the ordinary hours of work (6.45–7.45, 8.45–11.30, 1.45–3.45), were resumed.

It was found that with the shifting mud below the platforms much

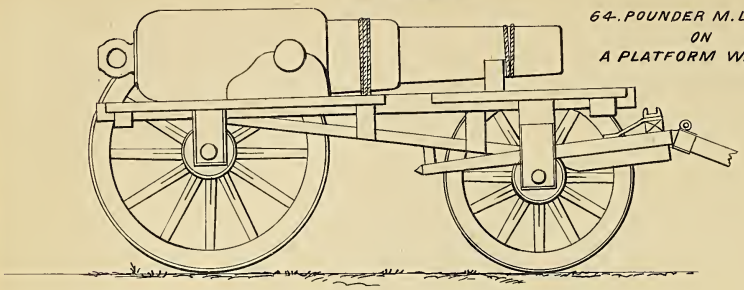
greater command was obtained over the columns of skidding by using two columns to each jack; thus being able to throw the weight on the outer or inner side of the platform, according as one or the other sank

Fig. 13.



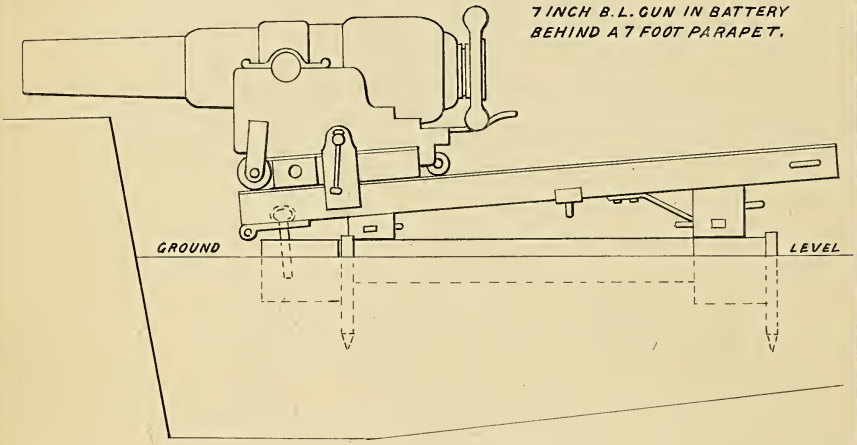
most, thus restoring the horizontal position without relaying the platform—which would have been impossible, when the weight was once taken, till the skids *ZZ* were placed under the gun.

DIAGRAM I.



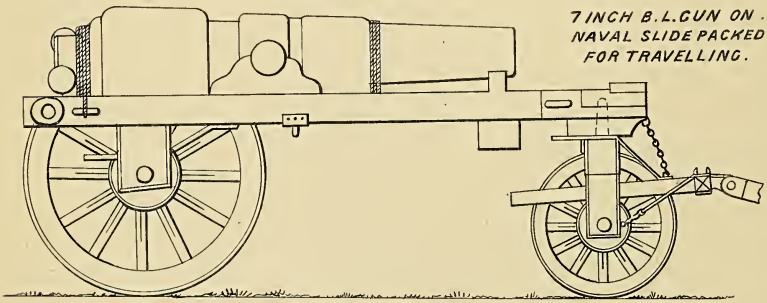
64. POUNDER M.L.GUN.
ON
A PLATFORM WAGON.

DIAGRAM II.



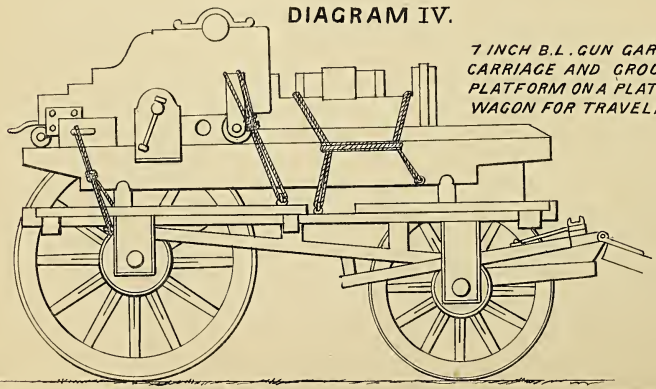
7 INCH B.L.GUN IN BATTERY
BEHIND A 7 FOOT PARAPET.

DIAGRAM III.



7 INCH B.L.GUN ON
NAVAL SLIDE PACKED
FOR TRAVELLING.

DIAGRAM IV.



7 INCH B.L.GUN GARRISON
CARRIAGE AND GROUND
PLATFORM ON A PLATFORM
WAGON FOR TRAVELLING.

THE COMPOSITION AND STRENGTH OF A SIEGE TRAIN REQUIRED FOR THE ATTACK OF A MODERN FORTRESS.

BY

COLONEL E. WRAY, C.B.,

ROYAL ARTILLERY.

Preliminary considerations.

BEFORE attempting to lay down siege equipments suitable to the requirements of the day, it will be necessary to consider two most important phases of the question.

1st. The nature and extent of the changes which have taken place in armaments, and, as far as may have been decided, in the method of attack, since the last siege operations were undertaken by the British Army in Europe.

Changes in armaments since the Crimean campaign, and the degree of importance to be attached to such changes.

2nd. The degree to which such changes have altered the conditions of the defence, as well as those of the attack, of fortified places.

The greatest difference of opinion prevails at this moment amongst the members of both Ordnance Corps on many of the points involved in the above considerations, some maintaining that the introduction of rifled artillery, small arms of precision, and Gatling guns, the adoption of the Moncrieff principle, and the use of curved fire for breaching unseen revetments, have, together with other novelties, revolutionised, if they have not rendered obsolete, the systems of Vauban and other great masters of the science of attack and defence; whilst not a few, especially amongst the older members of the Artillery, are sceptical as to any great advantage possessed by rifled arms over smooth-bores for siege purposes, take little account of the Gatling gun, or of the immense advance made during the last ten years in the range and accuracy of infantry fire, disbelieve in the efficacy of curved fire, and placing every confidence in embrasures and iron shields, or barbette batteries, have none whatever in the Moncrieff system.

Breech-loading and muzzle-loading guns.

Some, again, never cease to regret the withdrawal of the Armstrong guns from the armaments, and to claim for breech-loading a superiority over the muzzle-loading system, which the advocates of the latter as stoutly maintain.

Incomplete condition of the existing arrangements for conducting sieges in future.

As regards siege-carriages, platforms, brakes for checking recoil, holdfasts, as well as a host of details appertaining to the formation of works of attack, much remains to be corrected before the muzzle-loading siege train now under preparation can be considered fit to take the field. Nothing is definitely settled as to the proportions of fighting-men, drivers, artificers, or horses, required for working, repairing, or moving siege trains of any given strength; nor are the means at hand for readily ascertaining the weights of the various articles of equipment, so as to admit of their being distributed in loads suitable to the capabilities of the cattle of the country in which operations are to be carried on; whilst, as regards any detailed or even general plan for conducting a siege in future, absolutely nothing has as yet been determined.

Appointment of a committee to report on the subject.

It is true that a special committee is considering the subject, and endeavouring to extract from this chaos of opinion the data for establishing a system of attack suitable to the altered conditions of war, but as the results of these enquiries are not likely to be known for some time, it necessarily follows that the organisation of an equipment for siege purposes must in the interval be based on the individual views of any one undertaking to lay it down: the task thus becoming a much more difficult one than would be the case were any recognised rules for conducting a siege available.

The defence considered with reference to altered conditions.

In order to arrive at a just appreciation of the work to be performed at sieges in future, and to form anything like an estimate of the proper ordnance and material to be employed, it is advisable in the first instance to review briefly the measures likely to be adopted by the besieged for meeting the altered conditions which the introduction of rifled arms has undoubtedly imposed on both combatants; changes on the whole more favourable to the defence than to the attack, considering the vastly increased difficulty entailed on the latter, when every other obstacle has been overcome, in delivering the assault, if, indeed, it be possible to storm a breach at all in the face of resolute men, armed with breach-loading rifles, and with Gatling guns in the capponieres.

Advanced works.

It may be assumed that, in order to prevent the besiegers from destroying the flanking defences of a fortress, silencing its guns, or bombarding it at long ranges, powerful works mounting ordnance of the heaviest description would be placed at considerable distances in advance of the enceinte, casemates being extensively used for rendering these defences impervious to vertical fire.

Casemates and the probability of much heavier guns being used by

The perfection to which the construction of overhead-cover has been brought would ensure this, but the faces of such batteries must always be more or less exposed, in order to enable their guns to be used at short ranges; and it is quite certain that masonry

or brickwork, however strong, must rapidly succumb to the direct battering of such guns as the 7-inch or 64-pr., even supposing their projectiles to be only charged with gunpowder. It is, moreover, apparent that the fire of the guns exposed behind such open shields as have been adopted for the sea faces of coast batteries, could with ease be kept down by the light guns of the attack, whilst the process of demolishing the intervening masonry proceeded.

the defence in future.

Masonry and brickwork defences.

Iron-plated embrasures.

It would, of course, be necessary to reduce one or more of these isolated strongholds before any advance could be attempted on the main works of the besieged, and as their heavy artillery might fairly be expected to sweep away any fieldwork of the ordinary type which it would be possible to construct in a single night, the only chance of establishing breaching batteries within a reasonable distance of such works would appear to be in the employment of guns mounted on the Moncrieff principle, placed in pits or trenches, or sunk behind such inequalities of ground as would render them safe from the direct fire of any gun that might be brought against them.

Moncrieff system the best for close attack.

By multiplying the number of 7-inch and 64-pr. guns, and employing them, as above suggested, for "over-bank direct fire" at distances of 800 to 1,000 yards, supplementing them largely with 8 and 6·3-inch howitzers, for "curved fire," the superior weight of metal thrown by the defenders might be counterbalanced, without resorting to the employment of heavier guns, which could only be taken to a siege by railway, and into the trenches by tramways and locomotives.

Possibility of meeting the heavy artillery of the defence with a largely increased number of heavy siege guns, capable of travelling over ordinary roads, without resorting to railways.

It is quite within the bounds of reason to anticipate that the plating of forts with iron will be extended to land-fronts, and that "muzzle-pivotting" carriages may be introduced for casemates, in which case guns of 12 and 18 tons would have to be taken to the front; but any dissertation on this large question would be out of place here, the object of the Essay being presumably the development of a siege train in the sense of the term hitherto accepted, viz., such as would, under ordinary circumstances, accompany an army on a campaign, and be capable of travelling over rough roads and such ground as the approaches to the trenches might be expected to present.

Ironclad forts, and muzzle-pivotting carriages.

Having sketched as above the capabilities and resources of the defence, the next subject for consideration is

The Proportion of Ordnance that should be allotted to Siege Trains.

The Ordnance Select Committee, in 1864, recorded their opinion that "now-a-days there can be no such thing as a pattern Siege Train, as the composition of any Siege Train must depend upon the nature of the operations to be provided for and the theatre of war." Further, "that a certain number of 20-pr., 40-pr., 64-pr.,

The proportion of ordnance for siege trains to be determined at the time of opening a campaign.

and 7-inch guns should always be kept ready, with all needful stores, for siege purposes."

The regulations of the service* provide that, "whenever the formation of a Siege Train may be necessary, the number and description of guns will be fixed by the Secretary of State for War in communication with the Commander-in-Chief, according to the nature of the service or description of fortress likely to be attacked."

The new system of siege-train units.

Notwithstanding the above excellent arrangements, by which the nature and proportion of ordnance to be taken to a siege is left to be determined at the time by the circumstances of the case and the service to be expected, another system has lately crept in of laying down "Heavy and Light Siege Train Units" of 30 guns each; but it is manifest that under this plan any change found desirable or necessary in the armaments might at the last moment disarrange the whole train, whereas, by treating each gun as a unit, and keeping a proportion of each nature in reserve, complete in every respect, a siege train of any size and form required could, by a mere multiplication of units, be prepared in a few days, its establishment of men, horses, artificers, and stores calculated, and the weight of every load composing it accurately determined.

Advantage of treating each gun as the unit.

Description and Weight of Ordnance to be employed.

Adoption of 7-in. B.L. guns of 72 cwt. for the siege train.

In 1864, the Field-Marshal Commander-in-Chief called for information as to the greatest weight of gun that could be conveniently used with siege trains; and recorded his opinion, that, "provided the 7-inch B.L. gun could be so used, guns of that nature should form a considerable part of the future equipments for siege purposes."

After a series of trials for travelling the gun on a naval slide, fitted with transporting axle, 25 of these guns of 72 cwt. were added to the breech-loading siege train, of 105 pieces.

7-in. M.C. of 90 cwt.

There appears to be no reason why this weight should not be slightly exceeded; and accordingly a 7-inch gun of 90 cwt., to carry a projectile of about 115 lbs., is to form part of the muzzle-loading siege train.

64-prs.

These guns, with the 64-prs. of 64 cwt., should be employed for breaching by direct fire, and be mounted, as hereafter described, for close attack.

40 and 25-prs.

The lighter muzzle-loading guns, introduced for siege purposes, are the 40-pr. of 35 cwt. and the 25-pr. of 18 cwt. on travelling carriages.

8-in. and 6·3 Howitzers.

The muzzle-loading rifled howitzers hitherto manufactured, viz., the 8-inch of 46 cwt. (length 5ft. $1\frac{1}{4}$in.), and 6·3 inch of 18 cwt. (length $4\frac{1}{2}$ft.), have proved too lively for travelling

* Paragraph 51, page 21, 'Regulations for the Supply of Military Stores to an Army in the Field.'

carriages, and not sufficiently accurate* for breaching purposes. They will be removed to the category of rifled mortars; and for the first will be substituted a howitzer of 70 cwt., to be mounted on a bed, fitted with transporting axle and wheels, and for the second, a longer piece of about 35 cwt., suitable for the carriage of the 40-pr. M.L. gun.

Proposed conversion to Mortars and substitution of new patterns.

It now becomes a serious question, whether some portion of our vast and valuable supply of Armstrong breech-loading guns should not be made available for siege-train purposes. The objections to the system have to a great extent disappeared with the introduction of pebble powder, and there can be no question that their remarkable accuracy would render them extremely useful at a siege for dismounting guns and destroying works at long ranges.

Breech-loading Armstrong guns, their great accuracy.

For more advanced positions, where every inch of cover for gun and detachment is of vital importance, and the use of embrasures out of the question, the muzzle-loader, traversed by side-tackle from under the parapet, and loaded with a rope or telescopic rammer, is better protected than a breech-loader, and, considering its simplicity, may be taken as the better gun of the two, for close quarters.

Advantage of muzzle-loaders for more advanced positions.

There is practically no more difficulty in working one than the other, and it may be taken for granted that the gunners of the Royal Artillery are equally handy at either. Under these circumstances, a proportion of 7-inch, 40 and 20-pr. B.L. guns, with their equipments, should form part of the siege-train reserves, in the event of their being required at any time for the service of the country.

Addition of a proportion of 7-in.40-pr. and 20-pr. to the reserves.

The accompanying table shows how greatly the strain on the different siege-train guns is reduced by using pebble powder, and points to the possibility of greatly increasing their battering effect by "chambering" them. By adopting carriages with slides and compressors, the addition to the charge would be limited only by the capacity of the gun to consume it.

Table showing how the battering powers of siege guns may be increased.

GUNS.	Weight of Shot.	Charge.		Mean Muzzle Velocity, feet per second.	Maximum Pressure in Tons, per square inch on bottom of bore.
		R. L. G.	Pebble.		
	lbs.				
7-inch, M.L.	115	14	...	1205	14·3
		...	17	1213	9·0
64-pr.	64	12	...	1450	22·0
		...	16	1500	8·9
40-pr.	40	7	...	1301	27·0
		...	10	1495	8·3
7-Inch, B.L.	90	11	...	1225	17·4
		...	14	1188	5·0

* The rifling of the 6·3 inch howitzers has lately been changed, and their shooting greatly improved, but both the present howitzers are too light, and in reality are only fit to be classed as mortars.

Siege Train Carriages.

Carriages for siege-train purposes.

A judicious selection of the best system of mounting the guns of a siege train forms by far the most important feature in its organisation, and as the work to be performed is of various kinds, each requiring special consideration, it may be as well to divide the carriages into distinct classes, as follows:—

1st. Travelling carriages.
2nd. Carriages required for the more powerful battering guns, firing very heavy charges.
3rd. Beds for howitzers, firing lower charges, but much heavier projectiles.
4th. Elevated carriages on wheels, for over-bank direct fire.
5th. Carriages of the Moncrieff type.

Travelling carriages for guns of 35 cwt. and under.

The use of travelling carriages for the 40 and 25-pr. M.L. and the 40 and 20-pr. B.L. guns is no doubt as it should be, as these guns at a siege may be frequently removed from point to point, and they are besides susceptible of transfer elsewhere for batteries of position.

The difficulty of working the 64-pr. with heavy charges.

But experience * has long shown that the 64-pr. is far too heavy a gun for a travelling carriage, and it is invariably transported on a platform wagon (as in Diagram I.), whilst the difficulty of checking its recoil is already so great, even with a 12-lb charge and 64-lb. projectile, as to render a wheeled carriage practically inadmissible for fighting it upon. When the charge is increased, and a 90-lb. battering shot used as proposed, this carriage will certainly have to be dispensed with in favour of a garrison carriage,† with slide and compressor.

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* By the records of siege equipment sent to the Peninsula it appears that it was considered inexpedient in those days to transport even 24-prs. of 50 cwt. on travelling carriages, the whole of the guns of this weight, 75 in number, taken to the Siege of St. Sebastian, being provided with platform wagons.

† In India, travelling carriages are not, as a rule, employed at sieges for fighting purposes, but simply for transporting the guns from place to place, garrison carriages accompanying the train, on to which the guns are transferred when required for use. The following memorandum was submitted in April, 1804, to Major-General the Hon. Arthur Wellesley by a very distinguished general officer of Artillery, serving under his orders in India, and although these opinions are more than half-a-century old, they are based on a wide experience of siege operations, and may not be considered out of place in discussing the subject of siege equipments.

"I do not hesitate to give it as my opinion, from my own experience, that an error has been cherished by many Artillery officers respecting travelling carriages, following the construction given by authors and others who have gone before them, without allowing their own judgment to operate, and consequently conceiving that all descriptions of gun carriages, taken with an army into the field, whether for battering guns or otherwise, should be constructed in some degree as field-piece carriages, on high-spoke wheels, and long cheeks. This, in my opinion, is by no means necessary. For what experienced officer, unless obliged, would think of transporting an 18 or 24-pr. battering gun on its own carriage? Therefore, if the battering guns of an army are to be transported on sling carriages or platform wagons, surely it is not necessary to construct carriages on these old heavy expensive principles, while the simple truck carriage answers every purpose. It is light, and easy to be conveyed by lashing it to the same carriage that transports its gun. I am, nevertheless, of opinion, that it is necessary in all large garrisons to have in store a few of what are termed 'travelling carriages' in case they should be wanted for emergent service."

There is no novelty in such an arrangement. The late Ordnance Select Committee in 1868, in view to the introduction of the 7-inch B.L. gun of 72 cwt. into the siege-train, carried out a series of experiments for working this gun on a wooden garrison carriage and naval slide, with special ground platform, as shown in Diagram II., and travelling it with its appliances, as in Diagrams III. and IV.*

The 7-in. B.L. gun on garrison carriage and slide with compressor.

The introduction of this system of mounting siege guns contemplated at that time their use behind embrasures, but it is evident that any advantage as to cover attainable with a gun on a travelling-carriage is to be gained by a simple adaptation of the ground in rear of the parapet, as shown in Diagram II.

The low carriage adapted for firing over a high parapet.

Looking, therefore, to the circumstance that travelling carriages are not used for the transport of such heavy guns as the 64-pr., that when mounted on wrought-iron garrison carriages and slides they can be kept by compressors within perfect control, with any charge that the gun will burn, and, further, that nothing is gained as regards height above plane by mounting them on wheels, it is proposed, in laying down a siege equipment, that the system of mounting and travelling the 7-inch B.L. gun adopted by the O. S. Committee be taken as a guide for designing the carriages and platforms of all siege guns and howitzers exceeding the 40-pr. in weight,† with the following modifications:—

Advantage of garrison over wheeled carriages for heavy battering guns.

1st. The garrison carriage or bed to be of single-plate wrought-iron, instead of wood.
2nd. The slide of wrought-iron, with compressor or hydraulic buffer, as found best.
3rd. The platform to be of the type used with the 7-inch, but decked over to give greater facility for working, and a more extended traverse to the gun.

Proposed modification in the B.L. 7-in. equipment to adapt it for 7-in. M.L., and 64-pr. guns, and 8-in Howitzer.

The following comparison shows approximately the saving to be effected in the weight of equipments for 64-pr. guns, and 8-inch howitzers, by mounting and travelling them as proposed.

THE 64-PR. R.M.L. GUN.

AT PRESENT.	Cwt.	Cwt.
64-pr. Gun	64	86
Platform Wagon	22	
Wrought-iron Travelling Carriage	32	45
,, Limber, Siege ...	13	
Ordinary Ground Platform, large‡	35	57
Platform Wagon	22	
Total ...		188

AS PROPOSED.	Cwt.	Cwt.
64-pr. Gun	64	86
Platform Wagon...	22	
Wrought-iron Garrison Carriage	12	62
,, Slide, with Compressor	18	
Special Ground Platform 17		
Travelling arrangement, with Dilly	17	
Total ...		150

Great waste of horse power by the existing arrangements.

Difference in favour of the proposed plan—2 Tons = at ½ a ton per horse, to a saving of 4 horses per piece, or the power of 32 horses for 8 64-prs. in each unit.

* The 'Royal Carriage Department Notes' of 31st July, 1869, show that the plan was accepted, and 25 sets are in reserve.

† Any 64 or 8-inch howitzer travelling carriages already made being kept for special service.

‡ For the weight of these platforms, *v.* page 37, 'R. C. D. Notes,' of 31st July, 1869.

THE 8-INCH R.M.L. HOWITZER.

	Cwt.	Cwt.
8-inch Howitzer	46	
Wrought-iron Travelling Carriage	43	102
„ Limber, Siege... ...	13	
Wrought-iron bed *	25	
Compressor bar *	8	
Platform, special *	15	105
Ordinary ground Platform, large †	35	
Platform Wagon	22	
Total ...		207

	Cwt.	Cwt.
8-inch Howitzer	46	68
Platform Wagon	22	
Wrought-iron bed	25	
„ Slide, with compressor	20	79
Special ground Platform	17	
Travelling arrangement, with Dilly	17	
Total ...		147

Difference in favour of the proposed plan—3 Tons = at ½ a ton per horse, to 6 horses per piece, or the power of 84 horses, for 14 howitzers in each unit.

Total saving in each heavy unit of the Siege Train—116 horses.

Elevated Wheeled Carriages on the German Model.

Direct over-bank fire at long ranges.

It was found at the Eastbourne experiments last autumn, that at a thousand yards, guns thus mounted could be very quickly disabled by guns fired on the same level, and the conclusion arrived at was, "that a gun in a fixed position for over-bank fire is too exposed, unless it has a command of fire." But it by no means follows, that, because two guns were so disabled at this short range, under most favourable circumstances, the barbette system may not be found thoroughly effective at longer distances; indeed, such would appear to be the general opinion abroad, as elevated carriages for direct over-bank fire are being extensively adopted by foreign artillerists.

As, however, the same cover can be obtained with a low carriage (*v.* Diagram II.) by placing the gun on a high level and sinking the detachment, the necessity for these special carriages is not apparent.

Moncrieff Carriages.

Curved fire, necessity for providing other means of breeching.

Breaching by "curved fire" from behind unbroken parapets has not as yet been practised in this country, and little is known on the subject beyond reports from abroad, but however effective it may prove on trial, it is not considered desirable to abandon the use of direct fire for breaching, and the majority of opinions are favourable to the introduction of carriages which "will allow a gun to be raised into the firing position from cover."

New designs of carriages on Moncrieff principle.

The adoption of Moncrieff carriages‡ for siege purposes, worked on the hydro-pneumatic principle, has for several years been under consideration, and new designs have lately been called for. Two

* The 8-inch howitzer on a travelling carriage is unmanageable, with charges over 5 lbs. and a bed with special platform, the latter, differing from that used with it when firing from its travelling carriage, has to be provided, in addition, for firing at high angles and with increased charges. It will be observed that the weights, 102 and 105 cwt., are excessive for a travelling siege train.

† For the weight of these platforms, *v.* page 37, 'R. C. D. Notes,' of 31st July, 1869.

‡ The Moncrieff counterweight carriages, introduced for the 12 and 7-ton M.L. guns, are no doubt unnecessarily complicated, but they have been made so by a number of mechanical contrivances for doing what, in action, or when firing service charges, is the work of recoil, and which could be equally well performed, as a mere drill

carriages for 64-pr. of the "travelling" type are being manufactured by Major Moncrieff, and a proposal has likewise been submitted by the Royal Carriage Department for working a gun behind a 7-foot parapet on somewhat the same principle, by arms attached to brackets fixed to a wrought-iron platform instead of to a carriage, thus gaining greater stability, avoiding the difficulties connected with recoil inherent in wheeled carriages, and enabling the guns to be used with greatly increased charges. R. C. D. adaptation.

If this arrangement could be applied to the slide proposed in these papers for the 7-inch and 64-pr., and the elevating apparatus made removable, it would only be necessary to provide each battering gun with a set, which could be fixed to the slide when required for close attack. The apparatus would travel with the garrison carriage and ground platform *on* the slide, and the gun on its platform wagon. Removable arms, &c., for converting ordinary slides into Moncrieff carriages.

Proportion of Spare Carriages to accompany a Siege Train.

There should be one spare carriage to every 10 guns, and the same proportion of sling wagons when marching, in case of accident, to ordinary transport. Spare carriages and sling wagons.

One forge wagon, with a store limber wagon for carrying repairing stores for three months, should be allowed to every ten guns, for keeping in order both the fighting and transporting portions of the train, including the shoeing of horses. Forge and store wagons.

Platforms.

It has been decided to adopt the ordinary ground platform* in preference to either of the portable platforms, "Clerk's" or "Alderson's;" and, further, that all platforms shall be laid as heretofore by the Engineers.† Should the suggestion for mounting all heavier guns than 40-prs. on garrison carriage slides and special platforms be accepted, the ordinary ground platform would only be required for 40-pr. guns and 6·3 howitzers. Platforms for siege guns and howitzers.

Accessories to a Siege Train.

Two 7-pr. R.M.L. guns on wrought-iron beds should be allotted to every 10 siege guns, in lieu of Coehorns. 7-pr. rifled guns.

One hundred 24-pr. Hale's rockets are provided for every 10 guns. When charged with gun-cotton these rockets will become a formidable addition to siege-train equipments. Most satisfactory experiments have already been carried out with them. Gun-cotton rockets.

The means of keeping up telegraphic communication between the different batteries of attack should be provided for at future sieges. Telegraph stores.

A small-sized Gatling gun mounted on high wheels and axle adapted to the width of the advanced trenches, with a long light Gatling gun, 45-in.

operation, by block and tackle: but the carriages of the 7-inch B.L. and 64-pr. M.L. (converted) guns are simple and excellent, and, although unsuitable for a travelling siege train, are well adapted for defensive purposes, and would probably be found extremely useful in such a position as that proposed to defending Constantinople, or for earthworks of any kind. A considerable proportion of these carriages should be kept in store in readiness for such service.

* Some modification of the pattern laid down in 'R. C. D. Notes' of 1869, page 37, is being made, so as to reduce the excessive weights of these platforms.

† In India they are laid by the Artillery.

trail or perch suitable for hauling it rapidly from point to point, would be preferable to any field gun for repelling sorties, especially at night, owing to its uninterrupted fire and wide-spreading effect. The latest American pattern weighs only 75lbs. and fires 1,000 shots in 2½ minutes.

Wall pieces.

Wall Pieces.—With the object of penetrating the sand-bag coverings of riflemen, and so compelling them to feel that they are never safe, it is desirable that a weapon of this kind should be introduced for the advanced trenches. It should be fitted with a swivel and peg for driving into the ground to fire from the shoulder, through an opening in the parapet, and be thoroughly effective as regards accuracy and penetration at 600 yards, carrying a one-pound ball.

Ammunition.

Gun-Cotton or other Explosive for bursting Shells.—The introduction of some more powerful agent than gunpowder for bursting shells is only apparently delayed by the difficulty of finding an explosive which can be fired with safety to the guns, and it is evident that the adoption of such a ready means of reducing the labour of breaching is only a question of time.

Special Fuze for Breaching.—A percussion fuze sufficiently sensitive to admit of being set in action with a low charge, and yet be so retarded in its action on striking as to ensure the complete penetration of a shell before bursting, is indispensable for battering purposes.

Special Battering Projectiles.—Shells of 90lbs. weight, with chilled heads, to be used from the 64-pr. gun, are under trial, with a view to ascertaining if they possess any advantage over ordinary projectiles for battering solid masonry.

Packing Ammunition.—To avoid the inconvenience of carrying and storing powder in bulk, and the manipulation of it in the batteries, all cartridges should be filled and packed in metal-lined cases, the shells being loaded, and, together with case shot, carried in wooden boxes.

Charge of a Siege Train on Service.

When in regimental charge.

In ordnance charge.

There are two distinct conditions under which a Siege Train may be required for service. The first, when a siege has actually been determined upon, in which case the guns, ammunition, and stores required for immediate service are made over to the Artillery and embarked with the troops, the reserves being retained in ordnance charge in a field-park, to be established for the purpose, and drawn on as wanted. The second condition is when a Siege Train accompanies an army taking the field for general siege work, in which case it is sent to the base of operations in charge of the Ordnance Department, with which it remains until required for service.

The Personnel of a Siege Train.

Officers and men.

The establishment of officers and men to be provided for a Siege Train taking the field should be divided into two branches, viz., "the fighting and transporting."

Strength of detachments.

Establishment of Fighting Men.—The number should be calculated by batteries, according to the guns to be employed, allow-

ing an average of one garrison battery of six officers and 116 non-commissioned officers and men to every three guns. This is the proportion laid down in Major Miller's compilation of 'Army Equipment Regulations,' page 14, as suitable for smooth-bore siege guns, and may be accepted for rifled guns, the average strength of detachment for working guns, up to the 7-inch inclusive, being nine.

Thus three reliefs are provided of ten men each, with a proportion of spare for servants, camp duties, and casualties.

It is not necessary to define the personal equipment of the batteries thus attached to the Siege Train, as it is provided for in the regulations.

Drivers, horses wagons.

Transporting Establishment.—The transport service of a Siege Train must almost in all cases depend on the means available from the general transport of the army, aided by the carriage of the country, for taking the guns and ammunition to the front; but it is highly desirable that a certain proportion of drivers, horses, and artillery wagons* should be permanently attached to the train for forming a nucleus to which to attach the drivers and cattle obtained from other sources.†

The following detail of men and horses allowed for the reserve ammunition of an army corps would form a suitable permanent establishment in the field for a Siege Train of from thirty to sixty pieces of ordnance:—

OFFICERS AND MEN.		HORSES.			
		Riding:—			** Two are the private property of the Veterinary Surgeon.
Captain ...	1	Officers'	**7		
Lieutenants ...	2	Staff-Sergeants' ...	2		
Quartermaster ...	1	Non-Commissioned Officers'	9		
Assistant-Surgeon	1	Farriers'	1		
Veterinary Surgeon	1	Trumpeters' ...	2		
Non-Commiss. Officers and Men:—		Spare	2		
Sergeant-Major...	1		23	*Artificers' Tools:—*	
Quartermaster-Sergeant	1	Draught	160	Collar-makers' sets	3
Sergeants	6			Farriers'	4
Corporals	6	Total horses ...	183	*Material for Repair:*	For Wheelers' tools and material, *v.* list of Siege Train stores.
Drivers	87	*Saddlery Sets:—*		Collar-makers', sufficient for 3 months.	
Trumpeters ...	2	Officers'	5		
Artificers:—		Universal	16		Artificers for repairing harness and saddlery and for shoeing.
Sergeant Farrier	1	*Harness:—*			
Shoeing Smiths...	6	Double Sets—			
Collar makers ...	3	Lead	35		
Total, all ranks	119	Wheel	45		

Artificers for repair of carriages.

Siege Train for Artificers.—The proportion of wheelers allowed to a battery of field artillery, viz., one to three guns, would not be excessive for a Siege Train, taking into account the large number of carriages employed in transporting the stores and ammunition.

* Proportion, two per gun. These wagons should be fitted to take ordinary farm harness if required, as in the case of the carriages for 40-pr. guns of position.

† Colonel St. George, R.A., in reporting on the siege operations before Sebastopol, gives it as his opinion that from 60 to 200 horses should be permanently attached to the Siege Train, and Major-General Sir Richard Dacres strongly advocates the use of wagons and carts, specially fitted for carrying shot and shell, with frames fitted in them that can be altered according to the size required.

NOTE.—In India selected animals (generally Government cattle) are invariably

ORDNANCE FOR SIEGE TRAINS.

	How Travelled and Worked.
Muzzle-loading Rifled Guns.	
7-inch of 90 cwt.	Guns travelled on Platform Wagons.
64-pr. of 64 cwt.	Guns worked on wrought-iron garrison carriages and slides, with special platforms. The slide fitted with travelling axle, for transporting the carriage and platform.
40-pr. of 35 cwt.	Travelled and worked on wrought-iron travelling carriages, with field limbers.
25-pr. of 18 cwt.	An ordinary ground platform for the 40-pr.
Muzzle-loading Rifled Howitzers:—	
8-inch of 70 cwt.	Same as the 7-inch, and 64-pr. M. L. Guns, but worked on a wrought-iron bed instead of a garrison carriage.
6·3-inch of 35 cwt.	Same as the 40-pr. M. L. Gun.
Rifled Mortars:—	
8-inch of 46 cwt.	Same as the 8-inch Howitzer.
6·3-inch of 18 cwt.	Either on a 40-pr. travelling carriage or a special bed with ordinary ground platform.
Breech-loading Rifled Guns:—	
7-inch of 72 cwt.	Same as the 7-inch M. L. Gun, but with a wooden garrison carriage and naval slide, instead of wrought iron.
40-pr. of 35 cwt.	Travelled and worked on wooden travelling carriages with field limbers.
20-pr. of 16 cwt.	An ordinary ground platform for the 40-pr.
Accessories:—	
7-pr. R. M. C. Gun of 200 lbs.	Worked on a wrought-iron bed, carried in ammunition store wagons.
24-pr. Hale's Rockets	With two troughs per hundred rockets, carried in ammunition store wagons.
Gatling Guns of 75 lbs. ...	On special carriages with high wheels, travelled, lashed behind any of the carriages or wagons.
Wall pieces	Carried in ammunition store wagons.

PROPORTION OF AMMUNITION AND STORES FOR EACH PIECE OF ORDNANCE OF EACH NATURE (MUZZLE-LOADING AND BREECH-LOADING) TO BE USED FOR SIEGE TRAINS.

Ammunition and Combustible Stores.

Vocabulary Section.	Articles.	Proportions.	Where Carried.
V.	Balls, light-ground spherical, 8-inch	5 per 8-in. Howitzer or Mortar	Packed 3 in a box, carried in ammunition store wagons.
V.	Carcasses filled	30 per 8 and 6·3 Howitzer or Mortar	Packed 1 in a box do.
V.	Cartridges filled and in paper covers (Silk cloth for M.L. & serge for B. L. Ordnance)	Full battering charges of pebble powder for 400 rounds of 7-in. (M.L. or B.L.) and 64-pr. guns. with 100 rounds of ordinary charges.* 500 rounds of ordinary charges* for all other guns, 1/5 full, 2/5 half, and 2/5 quarter charges for Howitzers and Mortars. 150 6-oz. silk cloth cartridges for 7-pr. guns.	Such cartridges as are not stowed in the limber-boxes of travelling carriages, to be packed in metal-lined cases, and carried in ammunition store wagons
V.	Cartridges, shalloon, 4-ozs.	350 per 7-pr.	
	Cups, tin, 7-inch, B.L.	1 per round.	In boxes of 100

provided for the guns and more important carriages of a Siege Train, the remaining equipments and stores being carried on hired transport.

* The battering and ordinary charges of all guns to be decided by experiment.

Note.—It is essential that the weight of every article of siege equipment should be carefully ascertained, so that the loads may be readily calculated and distributed at any moment.

		MUZZLE LOADING.								BR. LOADING		
		GUNS.					HOWZR.		MORTRS.		GUNS.	
		7in.	64p.	40p.	25p.	7p.	8in.	6·3	8in.	6·3	7in.	40p.	20p.
Voc. Sec. V. Fuzes, percussion.	Plain												480
	R.L. II.	400	400	350	300	200	350	350	140	140	500	400	
Voc. Sec. V. Fuzes, time, wood boxes.	B.L. 20 secs.											40	
	B.L. 9 „											30	
	B.L. 5 „											20	
	M.L. 20 secs.	30	30	75	100	150							
	M.L. 9 „	15	15	70	80	200							
	M.L. 5 „	15	15	35	50								

Each plain percussion fuze in a waterproof bag, 2 fuzes in each canister, 40 canisters to a case

R.L. percussion fuzes in cylinders of 5 each, packed in wooden boxes of 6 cylinders each

In cylinders of 5, 6 cylinders in a box

In cylinders of 5, 6 cylinders in a box

NOTE.—Fuzes of all kinds to be kept in their cylinders, until actually required for use

Vocabulary Section.	Articles.	Proportion.	Where Carried.
V.	Handles, light, long	1 to 8 lights	With the lights
V.	Lights, long, G.S.	8 per piece	In cylinders of 4 each, 5 cylinders per box, with the handles and primers
V.	Lubricators, cartridge, 7-in.	1 per cartridge	24 in each box
V.	Match, slow [B.L.	1lb. per piece	In 3lb. bundles, made up into bales of 1ct.
V.	Portfires, common	4 per piece	12 in a bundle
V.	Primers: Gun Cotton for fuzes	1 cylinder per M.L. gun, Howitzer or Mortar	In cylinders of 20ft. lengths
V.	Primers: Light G.S.	10 primers for 8 lights	In cylinders of 5
V.	Primers: Vent piece	1 per round, 7in. and 40-pr. B.L. with 10 per cent. [spare	In cylinders of 25
V.	Rockets: War Hale, 24pr., with gun-cotton heads	10 per piece	6 in a box
V.	Rockets: Signal, 1lb., with sticks	10 per piece	60 in a box

		MUZZLE-LOADING.									BR. LOADING			
		GUNS.					HOWZR.		MORTRS.		GUNS.			
		7in.	64p.	40p.	25p.	7p.	8in.	6·3	8in.	6·3	7in.	40p.	20p.	
Voc. Sec. V.														
Shells with plugs filled	common	400	400	390	300	150	450	450	460	460	450	390	380	7-in., 64pr., and 8-in. Howitzer projectiles of all kinds, packed each in a box
	double segment					350					50	50	100	
	shrapnel	50	50	100	180							50		
Shells	battering	50	50											40-pr. do. 2 do.
	star						10	10	10	10				
Shot, case				10	20		10	10				10	20	25 & 20pr. do. 4 do.
V.	Tubes, friction, copper	550 per piece, including 7-pr.												In cylinders of 25, 4 cylinders in a box

NOTE.—Tubes to be kept in their cylinders until actually required for use

SMALL ARM AMMUNITION.

V.	Cartridge, ball	Gatling gun, 45-in.	10,000 rounds per gun	600 rounds in a box
		Wall piece	1,000 „	

Carried in Ammunition Store Wagons.

TOOLS, ENTRENCHING.

Vocabulary Section.	Articles.	Proportion.	Where Carried.
II.	Axes, pick, 6½lb., helved	1 per piece { with 1 to every ammunition store, forge, and store limber wagon	1 strapped on each siege and field limber. The remainder in ammunition store wagons
II.	Barrows, Hand	1 to every piece exceeding 35cwt.	In ammunition store wagons
	Barrows, Wheel	1 to 2 pieces do.	
IV.	Baskets, half-bushel	2 per piece	Do. do. do.
II.	Bars, iron crow, 5ft. 6in.	1 to each store limber wagon	In the wagon
II.	Rammers, earth	1 to 10 pieces	In ammunition store wagons
II.	Shovels, helved	1 of each per piece, with 1 of each to every ammunition store, forge, and store limber wagon	1 of each strapped on siege and field limbers. The remainder in ammunition store wagons
II.	Spades, do.		
	INSTRUMENTS.		
II.	Clinometers* (in lieu of quadrants)	1 to 3 pieces, including 7pr.	In ammunition store wagons
II.	Range finders,* complete	1 set to 15 pieces	
II.	Telescopes	1 to 8 pieces	
	STORES.		
V.	Bearers, shot or shell	1 per 7in. M.L. or B.L. gun 1 per 8-inch Howitzer or Mortar	Ammunition store wagons
V.	Beds, wrought iron	1 per 8in. Howitzer or Mortar 1 per 6·3-in. Mortar 1 per 7-pr. gun } with 1 to 15 spare	8-inch Howitzer or Mortar beds on slides, with travelling arrangement, 6·3 Mortar and 7-pr. beds in ammunition store wagons
V.	Bits, vent, Armstrong	1 to 2 B.L. guns	Do. do.
V.	Boxes, tin, grease, half-round lantern	1 to 3 pieces 1 to each lantern, brass, globular	1 strapped to each limber, ammunition store, forge, and store limber wagon
IV.	Box, stationery	1 to each store limber wagon	Part of the wagon
V.	Brushes, Gum, Piasaba, with stave	1 to 6 M.L. guns of each nature	Ammunition store wagon
IV.	Brushes, Water, carriage	1 to every piece on a travelling carriage, and 1 on every ammunition store, forge, and store limber wagon	Strapped on to the carriages
II.	Buckets, Leather, cavalry	2 per piece, with 2 on every ammunition store, forge, and store limber wagon	Slung under the carriages
V.	Buckets, Sponge	1 per B.L. gun	Do. and in ammunition store wagons
III.	Cans, tin, Lubricating, smith's	2 to 2 pieces over 35 cwt.	Do. do.
V.	Cans, tin, oil Travelling carriage	1 per piece on travelling carriage	Do. do.
V.	Caps, canvas, sponge	2 per piece, including 7-pr.	On the sponges
V.	Cartouches, canvas	2 per piece on travelling carriage	In the limber boxes
V.	Carriages, wrought-iron, complete :— Garrison, sliding, with compressors	1 per 7-in. and 64-pr. M.L. gun, with 1 to 15 spare	On wrought-iron slides with travelling arrangement
	Travelling siege with limber	1 per 40-pr. and 25-pr. M.L.gun, & 6·3-in. Howitzer, with 1 to 15 spare	

* Both should be of Captain Watkin's patterns.

Vocabulary Section.	Articles.	Proportion.	Where Carried.
V.	Carriages, wood, complete — Travelling siege, with limber	1 per 40 and 20-pr. B.L. gun, with 1 to 7 spare	On wooden naval slides, with travelling arrangement
	Sliding Naval B.L., 7-in.	1 per 7-in. B.L. gun	
V.	Cases:—Leather cartridge	2 per piece according to nature	Ammunition store wagon
III.	Leather, hand-saw, 26-in.	1 to each hand-saw	On the saws
V.	Leather vent-piece	1 per 40-pr. and 20-pr. B.L. gun	Strapped on the gun limber
V.	Clippers, port-fire	1 to 10 pieces	Ammunition store wagons
IV.	Cloths, sponge	6 per piece, including 7-prs.	In limbers of travelling carriages, and in ammunition store wagons
IV.	Cordage:—		
	Tarred, 4½-inch	2 fathoms of each per piece	
	4 „		
	3 „		
	2 „		
	1 „	4 fathoms of each per piece	In ammunition store wagons
	¾ „		
	Yarn, spun, hemp, 3 thread	5 lbs. per piece	
	White, 6-inch	1 fathom of each per piece	
	4 „		
	3 „		
	2 „		
V.	Covers, vent slot	1 per B.L. gun	On the guns
V.	Extractors, tin cup	1 per 7-in. B.L. gun	Ammunition store wagon
V.	Fids, wood, gun	1 per piece	With the gyns, on platform wagons
IV.	Grease, Fenner's	28 lbs. per piece, and for every wagon in the train	Reserve grease in excess of the supply with the carriages, packed in iron drums of 56lbs. each, total weight 2 qrs. 10lb.
V.	Gyns, triangle, 18 ft., light, wrought iron, complete with tackle, levers, slings, and trucks*	1 to 10 pieces over 35 cwt.	Platform wagons
		1 to 20 „ under 35 cwt.	
V.	Guns, Gatling, 45-in.	2 to every 10 pieces	On their carriages
IV.	Handspikes — Common 6 ft.	8 per piece, except 25 and 20-pr.	5 on each 40-pr. travelling carriage, the rest in ammunition store wagons
V.	Handspikes — Traversing	2 per 25 and 20-pr. guns	On the carriages
IV.	Hemp, undressed	2 lb. per piece, including 7-pr.	Part in limber box, balance in ammunition store wagons
III.	Hammers, handled, claw, 28 oz.	1 per piece	1 on each travelling carriage, the balance in ammunition store wagons
V.	Horns, powder, miners'	1 to 10 pieces	
V.	Implements, fuze and shell, parts of:—		
	Drivers, screw	1 per piece in battery, including 7-pr.	In limbers of travelling carriages, and in ammunition store wagons
	Extractors, fuze, small		
	Handles, hook, borer		
	Hooks, rock-borer, with bits		
	Keys, iron plug, G. S.		
	Drifts, wood		
	Instructions		
V.	Instruments, extracting projectiles, with bags	1 to 3 pieces (M.L.) of each nature over 35 cwt.	
V.	Jacks — Lifting, screw, Clark, with cover	1 to every piece of 35 cwt. and over	
	Jacks — Common field service	1 to every piece under „	On the limbers

* The head of a gyn projecting over the top of a parapet, serves as a mark to draw the enemy's fire, and this at the critical time when a number of men are collected together mounting

Vocabulary Section.	Articles.	Proportion.	Where Carried.
V.	Keys, spring lock	1 to every carrriage so fitted	With the men in charge
III.	Knives, clasp, with marline spike	1 per piece	Carried by the men
V.	Lanyards, friction tube Field and siege	3 to every piece, including 7-pr., and to each rocket trough	Limber & small store boxes of travelling carriages & in ammunition store wagons
IV.	Lanterns, brass globular, in box	2 per store and 2 per forge limber wagon	
V.	Levers, iron, for relieving vent-piece	1 to 2 7-inch B.L. guns	Ammunitn. store wagons
V.	Levers: Iron-shod crow, 7ft	1 to 4 pieces over 35 cwt.	
	Wood, 8ft.	1 to 8 pieces	
IV.	Line, Hambro	1 skein per piece	
V.	Linstocks, with cocks	1 to 8 pieces	
V.	Machines or trough, rocket, 24-pr.	2 per 100 rockets	
IV.	Marline	1 lb. skein per piece	
IV.	Oakum, tarred	1 lb. per piece	
IV.	Oil, Lucca	1 quart per piece	
III.	Pincers, carpenter's	1 pair per piece	On travelling carriages, and in the ammunition store wagons
	Planks, wood, for moving guns, 10 ft. by 17 in. by 5 in.	2 per piece	In platform wagons, with the guns
V.	Platforms: Ordinary ground*	1 per 40-pr. M.L. and B.L. and 6·3 Howitzer or Mortar	*To be carried and laid by the Royal Engineers
	Special	1 per 7-in. M.L. or B.L., 64-pr. M.L. and 8-in. Howitzer or Mortar	
V.	Pockets: Tube with straps	2 per piece, including 7-pr.	In limber and small store boxes of travelling carriages, and in ammunition store wagons
	Buff Fuze do.	2 per piece, except 20-pr. B.L., & including 7-pr.	
V.	Prickers, priming iron	2 per piece (M.L.), including 7-pr.	With the guns
V.	Rammers, gun, with wood staves	2 per piece	On travelling carriages, and for guns on garrison carriages in the ammunition store wagons
V.	Rods, pointing, with planks	1 per Howitzer and Mortar	Do.
V.	Rollers: Shifting gun	1 to 4 40-pr. M.L. & B.L.	On platform wagons, with the gyns
	Elm, 3 ft. by 6	1 per piece of 35cwt. & over	
V.	Ropes: Drag, heavy pairs	1 to every piece & platform wagon	With the carriages
	do. light do.	1 to every ammunition store forge and store limber wagon	
V.	Ropes, lashing wagon	Do. with 3 to every platform wagon	
III.	Saws, hand, 26-in.	1 to 3 pieces	
V.	Scales, hanging, with rods	1 set per travelling carriage	In ammunition store wagons
V.	Scotches, wood, elm, medium	1 to 2 pieces of 35 cwt. and over	
V.	Skids wood: Fir, 14 ft. by 8 in. square; oak 14 ft. by 5½ in. square, dismounting guns; 3 ft. by 9 in. by 6 in., 3 ft. by 6 in. sq., 3ft. by 3in. sq.	1 of each to 4 pieces of 35 cwt. and over	With the gyns on platform wagons

the gun. The Russians have adopted an apparatus designed by Colonel Redinsky for drawing mounted guns into position. This is done even up steep slopes by the gun detachment alone and without any exposure. It is of the nature of a capstan fixed on to a platform moveable on rollers.

Vocabulary Section.	Article.	Proportion.	Where Carried.
V.	Slides { Wood, fitted with travelling axle, and wheels, with dilly complete	1 per 7-in. B.L. gun	Used for transporting the garrison carriages on beds and special platforms
	Slides { Wrought iron* do.	1 per 7-in. and 64-pr. M.L. gun, and 8-in. Howitzer and Mortar	
III.	Spanners, M'Mahon's, 13 inches	1 per piece	On travelling carriages and in ammunition store forge and store limber wagons
V.	Spikes { Gun, common	2 per piece, including 7-pr.	In ammunition store wagons
IV.	Spikes { Marline, iron, $2\frac{3}{4}$lb	1 to 3 pieces	
V.	Sponges, with staves	2 per piece, including 7-pr.	On travelling carriages & in the ammunition store wagons
V.	Sticks, port-fire	1 per piece	
V.	Straps, lifting projectiles	12 to each 40-pr. M.L. or B.L., and 18 to each 25-pr. M.L. travelling carriage	In the limber boxes
V.	Tackles, gun, tarred, $2\frac{1}{2}$-in. rope, $12\frac{1}{2}$ fathoms, with 2 double 8-in. Admiralty blocks.	1 per 7-in. M.L. or B.L. gun, and 8-in Howitzer and Mortar	On platform wagons, with the gyns
V.	Tampeons, wood, gun	1 per piece, including 7-pr.	In the guns and Howitzers
IV.	Tarpaulins, 20 ft. by 10 ft.	1 to 4 pieces	Ammunition store wagons
IV.	Twine, whipping	1lb. per piece	Do.
V.	Vent servers, with lanyards	2 per 7-in. & 64-pr. guns, & 2 per 8 & 6·3 in. Howtz.	With the guns
V.	Wad-hooks	1 per 7-in. 64 and 40-pr. M.L. & 8-in. Howitzer	40-pr. on travelling carriage. The rest in ammunition store wagon
V.	Wall pieces, B.L.	2 to 10 pieces	
	Wagons complete { Ammunition store	2 per piece	† Includes 4 levers (2 of which are fitted with ropes), 1 breast rope, 33 ft. long, of $2\frac{1}{2}$-in. tarred rope, 1 sling, 9 ft. long from bight to bight of 5-in. white rope, 2 large and 2 small thimbles
V.	Wagons complete { Platform	1 per 7-in. M.L. or B.L., 1 per 64-pr., 1 per 8-in. Howitzer or Mortar, & 2 per gyn and tackle	
	Wagons complete { Sling, complete†	1 to 10 pieces	
	Wagons complete { Forge, limber	1 to 10 pieces	
	Wagons complete { Store, limber	1 to 10 pieces	
IV.	Wick, cotton lantern, flat, $\frac{5}{8}$-in.	3 yards per lantern, brass globular	Ammunition store wagon
V.	Worms, wad-hook	1 to 25 & 7-pr. & 6·3 Howtz.	In small store boxes
		MAGAZINE STORES.	
V.	Cases, powder, metal, lined	As required for cartridges	
IV.	Cans, tin, oil feeding, pint	1 to 10 pieces	
IV.	Cloths, hair, 15 by 12 ft.		
III.	Drivers, screw, shrapnel, large		
V.	Extractors, fuze, small	1 to 5 pieces	Some of these articles are carried in limber and small store boxes of travelling carriages. The remainder in ammunition store wagons
V.	Funnels, copper, cartridge	1 to 10 pieces	
V.	Gauges { Filled cartridge, ring brass, iron ring, shell or shot high	1 of each calibre to 5 pieces	
IV.	Hides, tanned	1 to 10 pieces	
V.	Keys { Copper metal, lined case	As required for the cases	
V.	Keys { Iron plug, G.S.	1 to 5 pieces	
IV.	Lanterns, copper magazine	1 to 5 pieces	

* Fitted with arms and apparatus for raising and lowering the gun on the Moncrieff principle, when required for close attack.

Vocabulary Section.	Article.	Proportion.	Where Carried.
V.	Measures, copper powder, 1 lb. ½ lb., and 1 oz.	3 of each to 10 pieces	
IV.	Needles, brass, 4-inch	2 per piece	Some of these articles are carried in limber and small store boxes of travelling carriages, the remainder in ammunition store wagons
IV.	Oil, Colza, gallons	1 to 5 pieces	
IV.	Scales, powder and weights, 8-lb.	1 set to 10 pieces	
IV.	Scissors, gunmetal, 9½-in.	1 pair to 5 pieces	
IV.	Scissors, trimming lamps	1 pair to 10 pieces	
II.	Tents, laboratory complete	1 pair to 10 pieces	
IV.	Wick, cotton, lantern, flat, ¾-in	10 yards per lantern	
IV.	Wadmil tilts	1 to 10 pieces	
V.	Shoes, magazine pairs	1 to 5 pieces	
IV.	Silk twist oz.	1 to 5 pieces	
IV.	Worsted, white, No. 14, oz.	1 to 10 pieces	

STORES FOR UNLOADING TRANSPORTS.

IV.	Anchors, small, 1½ cwt.		6	Per siege train — For base of operations
IV.	Blocks, Bothway, double	12-inch	9	
IV.	Blocks, Bothway, double	8-inch	9	
IV.	Blocks, Bothway, single	12-inch	9	
IV.	Blocks, Bothway, single	8-inch	9	
IV.	Blocks, Bothway, treble	12-inch	9	
IV.	Blocks, Admiralty iron-bound snatch	12-inch	9	
V.	Capstans, crab, complete		3	
IV.	Chains, iron, 9/16 inch, 5 fathoms each		9	
IV.	Cordage fathoms, tarred	4-inch	565	
IV.	Cordage fathoms, tarred	3½-inch	113	
IV.	Cordage fathoms, tarred	2½-inch	673	
IV.	Cordage fathoms, white	6-inch	30	
V.	Posts, picket garrison, 8 ft.		40	
IV.	Spars, 40ft. by 1 ft., with 4 sets of gear		12	

CAMP EQUIPMENT. *v. Equipment*, p. 121.

II.	Axes, felling, 4½lb., helved	1 per battery	Flanders camp kettles when supplied are issued in the proportion of 1 to 8 non-com. officers & men
II.	Axes, hand, 2lb., handled	2 per 15 non-com. officers and men	
II.	Blankets, Grey, field service	1 per non-com. officer and man	
II.	Blankets, Horse, or rug, with pad and surcingle	1 per horse. Transport Establishment	
II.	Buckets, leather, cavalry	1 per non-com. officers' and men's tents	
II.	Colours, camp, shalloon, with poles	1 per piece of ordnance	
II.	Cords, forage or heel rope	2 per horse	
II.	Covers, waterproof, horse or saddle	1 per set of harness or saddlery	
II.	Hooks, Handled, bill	1 to 15 non-com. officers and men	
II.	Hooks, Reaping	1 to 8 non-com. officers, Transport Establishmt.	
II.	Kettles, Camp, Flanders	2 for staff-sergeants, per battery	
II.	Kettles, do. Torrens	1 for 5 non-com. officers and men	
II.	Mallets, helved, for pegs	1 to 8 horses	
II.	Mauls, common, helved	1 to 50 horses	
II.	Nets, forage, pairs	1 per horse	

Vocabulary Section.	Articles.	Proportion.	Where carried.
II.	Pegs, wood, heel rope	2 per horse	
II.	Posts, wood, picket, 2½ ft.	6 for tarred & 4 for white rope	
II.	Ropes, picket, 3-inch — Tarred, 25 yards	1 for 15 horses or 1 for 9 horses	With 1 to every 3 pieces of ordnance for parking guns, magazines, &c.
	White, 16 yards	1 for 9 horses	
II.	Screens, latrine, complete	1 per battery	
II.	Shackles, leather, heel rope	1 per horse	
II.	Tents, circular, and tent appurtenances	1 to officer commanding 1 per battery for officers 1 per battery for guards 1 per 15 non-com. officers and men, exclusive of staff-sergeant 1 for servants of mounted officers 1 latrine tent for officers	Such articles as are not carried on the horses, or carriages; to be transported in genl. service wagons, specially provided
	Horse Appointment.		
II.	Bags, nose	1 per horse	
II.	Sacks, corn, 3 bushel	1 to 5 horses	
	Miscellaneous Stores.		
	Implements, Butcher — Blocks, chopping	1 per battery	Baggage—380 lbs. allowed for each officer
	Choppers	1 per battery	
	Cleavers	1 per battery	
	Knives	1 per battery	
	Saws, iron back	1 per battery	
	Machine, weight 28 lbs.	1 per battery	
	Steels	1 per battery	
	Weights, 14lbs. to ½ oz. sets	1 per battery	

Shoes and Nails—1 spare set of Shoes, with 3 sets of Nails, to be provided for each horse.

Vocabulary Section.	Tools, Artificers'.	Proportion.	Where carried.
III.	Aprons, leather, basil, brown	6 per forge wagon	
IV.	Cans, tin, oil, smith's	1 per set of smith's or wheeler's tools	
III.	Files, 2d. cut 12-in. — Flat, safe edge	1 per 7-inch B.L. gun	
	½-round	1 do.	
IV.	Forge, field service, complete	On each forge wagon	
III.	Hammers, sledge, smith's, 10 lbs.	1 per set of smith's tools	
III.	Lines, chalk, carpenter's, with ¼-lb. chalk	1 per set of wheeler's tools	In forge, and store limber, and ammunition store-wagons
V.	Machines, hand, rifling, complete	1 per train for each nature of B.L. gun	
III.	Reels, chalk, line, wood	1 per set of wheeler's tools	
II.	Saws — Cross cut, 5 ft., with handles & sockets	1 of each to 10 pieces of ordnance	
	Pit, 4 ft. 5 in., with handles & sockets		
III.	Stones, grind, in case, 14in.	1 in each forge wagon	
	Do. with trough, 30in.	1 to 30 pieces	
V.	Straight edge, breech screw, and vent piece	1 to 10 B.L. guns	
III.	Tools, chests, artificers', complete — Smith's, Wheeler's & Fitter's	1 to 10 pieces	

Vocabulary Section.	Tools, Artificers'.	Proportion.	Where carried.
V.	Tools, facing, B.L. guns	1 per every 10 B.L. guns of each calibre	
V.	Do. special do.	1 per 10 guns or under	
V.	Tools, venting, sets of, in chest	1 per train for each calibre	
V.	Wrench iron for fixing elevating racks	1 to 20 guns or under	
V.	Wrench iron, knock up SS	1 to 10 guns or under	
		SPARE PARTS.	
V.	Arcs, elevating	1 to every M.L. gun on travelling carriage	
V.	Axletrees, iron travelling, with linch pins and washers — 1st class, siege carriage, drilled	1 to every 10 M.L. guns on travelling carriage	
V.	Axletrees, iron travelling, with linch pins and washers — 1st class, transporting slide	1 to every 10 M.L. guns on slides	
V.	Axletrees, iron travelling, with linch pins and washers — 2nd class — Cart trench	1 to 30 carts	
V.	Axletrees, iron travelling, with linch pins and washers — 2nd class — Field wt. iron, drilled	1 to 10 25 pr. M.L. guns	
V.	Axletrees, iron travelling, with linch pins and washers — 2nd class — Limber do. siege do.	1 to 10 siege limbers	
V.	Axletrees, iron travelling, with linch pins and washers — 2nd class — wagon — Ammunition and store	1 to 30 wagons	
V.	Axletrees, iron travelling, with linch pins and washers — 2nd class — wagon — Platform, fore	1 to 20 wagons	
V.	Bars, prepared — Capstan crab	1 per capstan	
V.	Bars, prepared — Splinter — limber — field	1 to 10 carriages	
V.	Bars, prepared — Splinter — limber — siege	1 to 10 carriages	
V.	Bars, prepared — Splinter — wagon — Ammunition store and platform	1 to 10 carriages	
V.	Beds, wood, axletree, prepared — Cart trench	1 to 15 carts	In ammunition-store wagons
V.	Beds, wood, axletree, prepared — Wagon platform — fore	1 of each to 10 wagons	
V.	Beds, wood, axletree, prepared — Wagon platform — hind	1 of each to 10 wagons	
V.	Bushes — breech — copper	2 per 40 and 20 pr. B.L. guns	
V.	Bushes — breech — iron	1 per 7-inch B.L. gun	
V.	Bushes — vent piece, copper sets	1 for 2 of each nature of B.L. guns	
	Cap, squares, with keys and chains	2 per piece, including 7-pr.	
V.	Coatings, sponge	1 per 100 rounds of each nature of B.L. gun	
V.	Coins, wood — carriage	1 to 4 pieces	
V.	Coins, wood — hand	1 to 4 pieces	
III.	Couples, trace	2 per piece	
V.	Outriggers — limber, siege	1 to 10 limbers	
V.	Outriggers — wagon platform	1 to 10 wagons	
V.	Pieces, pivot for elevating arcs, complete	1 per arc	
V.	Pieces, vent	1 per B.L. gun of each calibre	
V.	Pins, iron — keep	1 to 2 B.L. guns do.	
V.	Pins, iron — lever	Ditto do.	
V.	Pins — 2-in. steel travelling carriage — 1st class	1 per 40-pr. and upwards, 1 per sling wagon	
V.	Pins — 2-in. steel travelling carriage — 2nd class	1 per 25 & 20-pr. Ammunt. store platform, forge, store limbr. wgns. & trench cart	
V.	Pins — main wagon — Ammunition store platform	1 to 20 wagons	
V.	Pins — breeching with loops for shafts — double	1 to 10 carriages	
V.	Pins — breeching with loops for shafts — single	1 to 10 carriages	

Vocabulary Section.	Tools, Artificers'.	Proportion.	Where carried.
V.	Rings, copper, vent-piece	2 per piece	
V.	Scotch carriage	1 to 4 carriages	
V.	Screws, breech	1 to 10 B.L. guns of each calibre	
	Cart-trench { near / off	1 of each to 15 carts	
	Shafts — Limber — field { near, also siege / off	1 of each to 4 limbers	Siege framed shafts on platform wagons, remainder on ammunition store wagons
	Shafts — Limber — siege { framed pairs, also platform and sling wagon / single, off	1 to 4 carriages	
	Shafts — Wagon, ammunition store	1 to 4 wagons	
	Shoes, drag { 1st class / 2nd class / platform wagon	1 of each to 15 carriages, as suitable	
	Sights — tangent scale / centre { fore / hind	1 of each to 6 guns and under	In ammunition and store wagons
	Sights — fore / muzzle / trunnion	1 to 3 guns and under	
	Sockets, metal, with set screw	1 to 6 7-in. B.L. guns	
	Swingletrees { No. 1 siege / No. 2 field	1 to 6, in addition to spare on carriages	
	Vents, spare	1 to 3 pieces of each nature	
	Washers, drag / Travelling carriage { 1st class / 2nd { metal nave / wood nave	1 to every carriage, according to the nature of wheel	
	Wheels — 1st class siege ... 5ft. 0in.	1 to 6 travelling carriages	
	Wheels — 2nd class — field { heavy 5ft. 0in. / light 5ft. 0in.	1 to 10, according to nature	
	Wheels — 2nd class — cart trench 4ft. 2in.	1 to 15 carts	
	Wheels — 2nd class — wagon { ammunition store, fore 3ft. 4in. / Platform { fore 4ft. 0in. / hind 5ft. 0in.	1 to 10, according to nature	
	Wheels, hand elevating	1 to 10 carriages so fitted	

Lists of "repairing material" for a three months' supply for the siege equipments above enumerated should be added to these lists. They should comprise the following:—

1st. For the wrought-iron carriages or beds, with slides and compressors, for M.L. 7-in and 64-pr. battering guns, and 8-in. Howitzers and Mortars.

2nd. For the wrought-iron travelling carriages for 40 and 25-pr. M.L. guns, and 6·3 Howitzers.

3rd. The wooden garrison and travelling carriages for 7-in. 40 and 20pr. guns B.L.

4th. Ammunition, store, platform, sling, forge limber, and store limber wagons.

EXPERIMENTS MADE IN RUSSIA

WITH

THE "LE BOULENGÉ" TELEMETER.

TRANSLATED FROM THE SPANISH BY

LIEUT. J. C. DALTON, R.H.A.

Translator's Preface.

The description of the following experiments appeared in a Brussels paper, and was taken from the "Invalide Russe." The instrument used was the telemeter, invented by Major Le Boulengé, of the Belgian artillery.

Before describing the experiments, it would be as well to explain the instrument.

Its object is to tell ranges by measuring the intensity of the report of a distant piece of ordnance. There are two classes of the instrument, and Major-General Voyle, Retired Royal (Bengal) Artillery, thus describes them in his "Military Dictionary":—

"The first is composed of a glass tube, provided with a graduated scale representing distances, and containing an index floating in sulphuric ether. The observer, after having previously brought the index to the extremity of the tube that corresponds with the beginning of the scale, places the instrument horizontally in his hand, and watches the enemy's position. As soon as he perceives the smoke of a gun, he brings the instrument suddenly into a vertical position, and the index descends along the tube; then, when the report is heard, he reverses the telemeter, and the index remains stationary. The division of the scale on which the index has stopped gives the distance between the gun and the observer.

"The second is made on the same principle, of such small dimensions, and of so compact a form, that it can be easily fitted in and carried by any small-arm. It is composed of a small crystal tube, closed at both ends, and filled with rectified benzine. In the tube an ivory index floats, painted red. The instrument is encased in the flat part of the stock of a rifle, perpendicular to the axis of the barrel. A small opening cut in the wood enables the reading of the scale. The mode of using it is very similar to the before-mentioned instrument, the rifle being turned instead of the hand."

In the description of the experiments it does not mention which of these classes of the instrument was used, but the results appear to have been satisfactory; and although the accuracy of an instrument such as this (the main principle of which is the velocity of sound) must depend greatly on weather, temperature, &c., still from these results one must consider the instrument well worthy of notice.

J. C. D.

Ballincollig,
18th June, 1877.

In the summer of last year the Russians made some experiments with the Le Boulengé telemeter, and they considered that the results then obtained warranted a more searching trial of the instrument. They therefore selected two officers of the battalion of rifles of Field Marshal Prince Bariatinsky to conduct the experiments.

Ten shots were fired at each range, and the mean was taken of the results at these ranges. The following table shows the results obtained by each officer:—

Measured distance in paces.*	Distance estimated by telemeter.		Mean distance estimated by two observers.
	1st observer.	2nd observer.	
600	570	600	585
800	763	780	771
1000	999	977	988
1200	1179	1180	1180
911†	909	913	911

* The Russian pace is equivalent to 0·7 mètres, or 2 ft. 3·5 ins.
† This distance of 911 paces was taken at random, and not measured until after the observations were taken.

The "Invalide Russe" says that from the above table it appeared that, out of 100 ranges taken, 74 indicated the distance within the limits of the line of demarcation, 21 within the limits of its radius, and only 5 without that limit.

The Brussels paper explains that probably the limit of the distances corresponding to each degree of the sight is that designated as the "limit of the line of demarcation," and consequently all the distances within this limit or its radius make up an exact graduation of the sight. We must remember that these experiments were made by men who did not know the instrument, and that only blank cartridge was used for the shots; the report, therefore, was not so *prononcé* as when using service charges and projectiles.

In the other experiments the soldiers adjusted their sights by the distances given by the telemeter, after having acquired confidence from its good results. When even the distances could be guessed by eye, the soldier did not always adjust the sight according to his estimate of the range, but preferred to take that given by the telemeter.

The other experiments were made in the following manner:—

Two guns were placed in position with their detachments, consisting of 1 officer, 2 gunners, and 12 men, representing the enemy. The detachment (formed of dummies) were so arranged that 1 ball could not penetrate more than 2 dummies.

The company of the regiment above-named, consisting of 48 files, with 10 N.C. officers, was taken away to an unmeasured distance until the artillery opened fire. This was done by 2 riflemen left with the guns, who fired each a shot and then retired quickly under cover. Profiting by these shots, the officer commanding the company measured

the distance to the guns by the telemeter, and imparted to his men the elevation they should give on their sights (according to the distance he had estimated). The company at once commenced a rapid fire, lasting 1 minute, firing 293 bullets, or 2·7 per man.

48 *took effect on the dummies, each of the latter being struck by from* 2 *to* 4 *bullets. All the bullets were distributed perfectly uniformly.* This alone proved, without measuring, that the telemeter had given the range correctly. After having measured the distance to the dummies, it was exactly 936 paces, and the telemeter having given 950 paces, the error was only 14.

The article in the Brussels paper concludes by recognising the practical utility in warfare of such a simple and portable instrument, the manipulation of which is so easy. Its principal use appears to be its power of paralyzing the efforts of the enemy at the commencement of the battle—that is to say, when it is possible to distinguish the report of the guns, and therefore to be able to measure the exact range with the telemeter.

This simple instrument is being tested by all countries, and consequently all concerning it is well worthy of observation and study. It has been studied in the Spanish army, and also in the School of Musketry at Toledo, and we hope very soon to be able to give account of the results of experiments with it.

SHRAPNEL FIRE.

BY

MAJOR S. J. NICHOLSON, R.H.A.

On the subject of the employment of shrapnel—which is in our service undoubtedly the principal projectile of the field artillery—a great divergence of opinion obtains, even amongst those who have given much thought and attention to the subject.

The number of questions on which there is this divergence is endless. Such, for instance, as under what circumstances time or percussion fuzes should be used; the best distance of burst for the former, or graze for the latter; at what ranges either are effective, and even at what objects; are only a few out of many. And yet these points are dependent on simple matters of fact which, if carefully worked out by experiment, clearly stated, and thoroughly considered, ought to lead, if not to an unanimous, at least to a more general consent than is now the case.

The present paper has no other pretension than to contain the opinions of a single individual, who would with all possible diffidence state them; not with any view of attempting the settlement of so large and important a question by doing so, but simply in the hope of inviting discussion, or—what is better—further experiment, and thus eliciting deductions more reliable and worthy of general acceptance.

Much of the diversity of opinion which exists is due, no doubt, to the somewhat rapid transition from the old spherical shrapnel to the segment, and so on to the present shell. The essential differences in action of the three have not perhaps been sufficiently remarked. With the first, the position of the bursting charge, relatively to the bullets, at the moment of the shell's opening was wholly uncertain, and the rotation of the shell equally so: there was comparatively a very large loss of velocity due to increased ranges, and the angle of descent was high; the ricochet was, however, very much more certain in direction. In the case of the second, the bursting charge was in the very centre of the segments, and gave a wide spread, and the form of these latter was very much against their retaining the velocity imparted to them by the shell. Though in principle the three may have a near alliance, in detail of action there is a wide difference between them.

This difference would sooner have been remarked had it not been for the unpractical manner in which, from circumstances nearly unavoidable, the annual practice of batteries has, for the most part, been carried on. The ranges have generally been over water, flat sands, or ground specially selected as offering as few obstacles as possible to efficient fire. A small barrel or a 6-ft. × 6-ft. target has been fired

at—a size of object which, if we except gun pits, is never likely to be the fact on service, where, as a rule, a large breadth or depth of ground has to be covered. In a word, neither the positions or targets have borne any resemblance to the exigences or realities of service.

To obtain the maximum effect on targets of such a nature, placed on ground so entirely favourable, has, however, very naturally been the aim of officers in command of batteries; and this has led to their having but slight opportunities of observing how greatly the action of the shell has altered; of arriving at the means by which its maximum results might be obtained; or of having forced upon their attention the fact that the rules which govern the use of shrapnel must vary with different objects and the ground on which they may be in position.

The main purpose of shrapnel must be steadily kept in view—viz., with a shell of a certain weight to cover any given area with as powerful and effective a bullet fire as possible, and thus to disable a large number of the enemy. To take an extreme case, for instance, we might suppose a battery, supplied with a solid shot of the same weight as its shrapnel, firing at a single rank. Each projectile could disable one man only; whereas it will be seen further on that a shrapnel, effectively burst with a time fuze, would account for from 19 to 23. It is to this crucial test of numbers disabled that all practice should be referred, since a shell that looks well in a Report may in fact be a very indifferent one. For instance, one in the Okehampton Report gives a total of 121 hits in a very small area. When it is analysed, it will be found to be as follows:—Throughs, 2; lodges, 3; strikes, 116. It is therefore wholly wanting in power. The number of dummies it disabled are two; it has no effective spread; it is, indeed, a good specimen of a bad shell.

The method generally adopted to test the practical value of any projectile is (1) to use it under circumstances as favourable as possible to bringing out and noting its maximum effect, and then (2) to use it under conditions as nearly as possible those which would obtain under ordinary circumstances, and thus find out how much of its maximum effect can be obtained on service. It it proposed to follow out the same principle in the present paper, by attempting to show (1), from some experiments carried out with great care at Shoeburyness and Okehampton, what are the maximum effects and the conditions necessary to attain them; afterwards, (2), from some experiments at Okehampton, how far such effect can be retained in practice.

The experiments at Okehampton must by this time be well known; those more particularly referred to will be shortly described in the proper places. The experiments at Shoeburyness are, however, less generally read, and may be shortly described; they may be found *in extenso* in "Extracts from the Quarterly Report of the Department of the Director of Artillery," Vol. XII., Part II., pp. 114–17. Three different patterns of shrapnel shell for the 16-pr. R.M.L. gun were to be tried. The target used consisted of a moveable screen, 18 ft. × 18 ft., which was placed at different distances in front of four rows of targets, 54 ft. × 9 ft. × 2 ins., 20 yds. apart. The shells were

burst with percussion fuzes through the screen, and thus the action of time fuzes was closely imitated, the height above plane and distance in front of object being capable of exact measurement. The ranges were 800 yds. and 1500 yds.—the latter being obtained by a reduction of charge, the guns remaining at the former distance.

Diagrams were taken of the targets, and the numbers of cavalry and infantry disabled were estimated by placing glasses over them, having figures drawn to scale. When any figure showed a hit or lodge it was counted as one; when two, as two men disabled; but any larger number did not affect the result.

Throughout the present paper, the effect on targets having 6 ft. height, or on infantry dummies, will, for the purpose of avoiding confusion, be as far as possible considered.

The effects produced by the shell most nearly identical with the present service pattern are given in Table I.:—

TABLE I.

Trial of 16-pr. Shrapnel Shell.

Shoeburyness, 26th to 29th May, 1874.

Range.	Burst in front of 1st Row of targets.	Height above plane.	Distance in rear of screen.	Effects on 4 rows of targets 54 ft. × 9 ft. × 2 ins., each 20 yds. apart.												Total effect on all 4 Rows.			Disabled on 1st Row.	
				1st Row.			2nd Row.			3rd Row.			4th Row.							
				Struck.	Lodged.	Through.	Struck.	Lodged.	Through.	Struck.	Lodged.	Through.	Struck.	Lodged.	Through.	Struck.	Lodged.	Through.	Cavalry.	Infantry.
yds.	yds.	ft.	yds.																	
800	200	14	—	1	13	7	2	1	5	1	3	2	—	—	1	4	17	15	8	8
"	"	13¾	—	1	16	7	2	7	1	—	4	2	—	4	1	4	31	11	14	12
"	"	14	—	1	17	6	—	5	2	—	3	2	1	4	—	1	29	10	15	12
"	"	15	—	—	10	2	—	2	3	4	4	2	—	5	1	—	21	8	8	6
"	"	14	—	4	12	10	1	8	4	—	3	1	1	4	1	—	27	15	12	12
"	150	9	—	—	15	16	3	9	4	1	3	3	1	4	1	—	23	17	17	13
"	"	10	—	—	17	16	2	11	7	1	9	1	2	3	1	—	38	26	19	16
"	"	9½	—	1	17	17	—	6	13	1	3	2	1	4	2	—	29	32	15	23
"	"	9	—	—	18	23	1	11	11	1	6	4	—	4	4	—	39	39	22	25
"	"	9	—	—	15	8	2	1	5	1	2	2	—	2	4	—	21	15	15	10
1500	"	8½	—	4	23	13	1	4	3	1	4	1	—	1	3	—	30	22	22	22
"	"	8	—	—	8	21	2	6	6	1	4	2	—	2	3	—	23	29	15	18
"	"	8	—	—	15	15	1	9	9	2	8	2	—	2	2	—	39	28	18	22
"	"	7	—	1	17	21	1	9	4	1	9	1	—	3	2	—	40	28	17	19
"	"	8¾	—	5	9	16	4	4	4	1	2	1	—	2	1	—	17	21	14	14
800	100	10	—	3	20	43	5	4	25	8	11	2	1	2	1	—	36	71	22	29
"	"	11½	—	3	16	30	1	5	13	5	6	3	1	1	3	—	28	49	25	23
"	"	8¼	—	2	34	30	9	11	17	3	7	1	—	3	3	—	52	51	21	26
"	"	10¼	—	—	27	36	5	2	24	4	7	3	—	1	3	—	39	66	25	28
"	"	10½	—	1	19	24	16	10	15	5	8	3	—	—	2	—	38	44	20	20
1500	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
"	"	1½	—	—	4	—	1	—	2	—	—	—	1	4	2	5	7	9	2	2
"	"	1¼	—	2	6	66	—	26	37	2	13	8	3	3	—	7	46	111	15	20
"	"	3½	—	—	6	92	1	12	42	6	17	7	3	2	—	10	37	141	13	18
"	"	7½	—	1	15	99	11	13	42	4	8	11	2	4	1	18	40	153	15	21
800	"	6½	2	3	3	105	5	41	35	5	8	18	2	5	—	16	57	160	12	26
"	"	5½	3	2	5	99	3	31	37	7	9	14	2	3	—	14	48	150	13	16
"	"	5½	—	5	7	89	1	23	36	2	9	11	4	2	2	12	41	129	15	23
"	"	9	—	8	2	103	4	34	44	3	7	24	10	2	3	25	45	174	16	21
"	"	5½	4	4	16	84	1	26	35	4	9	17	9	3	2	18	54	138	18	24

If the shrapnel shell of a field gun is burst lying at rest upon fairly level ground, the head and bullets will be found from 35 to 40 yds. to the front; the splinters, some to the right, some to the left front, nearly as far forward; and the base blown 50 or 60 yds. to the rear. If the 16-pr. M.L. shrapnel is burst enclosed between four 9-ft. × 9-ft. targets, the whole of the bullets and splinters will be found inside, and only two or three small dents will be visible on the targets. The same will be the case with the 9-pr. M.L., except that the dents will be hardly perceptible.

Any effect produced by the shell is therefore evidently not due to the bursting charge, which may be said to have practically no accelerating and but very little disturbing tendency.*

The destructive effect of the splinters and bullets—that of the latter being by far the most important of the two—is simply due to the velocity which the shell may have at the time it bursts, and which they, as component parts of it, retain. When the shell opens, they continue to travel forward with this velocity, and would move in lines *parallel* to what would have been the trajectory of the shell if it had not burst, were it not for three causes:—

1. The disturbing effect of the bursting charge.
2. The centrifugal force imparted by the rotation of the shell.
3. A loss of velocity, greater than that which the shell in its original condition would have experienced, due to the difference of their form and weight.

The first of these causes of disturbance is, as has been already shown, small, and as it is impossible to calculate its effects, it may be passed over without further consideration.

The centrifugal force may, however, be calculated, since the weight of the bullets, their position in regard to the centre of gyration, and the velocity of rotation are known. The resultant of this force and the forward motion imparted by the shell will give the primary direction of the bullets, and from this their path may be found. They will tend to spread equally in every direction from the centre line, and form a cone. The angle of this cone has been calculated by Lieut. Goold-Adams for a 16-pr. M.L. shrapnel shell, travelling with the muzzle velocity, to be $7\frac{3}{4}°$. Captain Fairfax Ellis estimated the cone formed by the shells during the practice at Shoeburyness, to which reference has already been made, to be 8° at 800 yds. from muzzle; and the writer of the present article arrived at the same conclusion independently, by careful measurements of the breadths covered by the cones on the diagrams of the same practice.

It is evident that since the velocity of rotation remains very much the same, whereas the velocity of translation suffers considerable diminution as the range increases, this cone of dispersion will gradually increase with the range.

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* An accident which happened at Woolwich may be cited in confirmation of this view. A driver belonging to a battery there, wishing to show a friend the action of a friction tube, put one in a shrapnel shell, and, steadying the latter with his foot, fired it. The only damage done was to his foot, which was slightly wounded. The friend escaped without injury.

The following may be suggested as the probable angles at ranges up to 3000 yds. :—

Under 500 yds.	7°	2000 to 2500 yds.	10°
500 to 1300 "	8°	2500 to 2800 "	11°
1300 to 2000 "	9°	2800 to 3000 "	12°

A few rounds would settle the question, and the practical value of such an experiment would be very great.

The third cause of aberration is that due to the difference in shape and weight between the bullets and the complete shell. The former are spherical, made of lead, and small; the latter elongated, composed of various metals, and comparatively large. The bullets begin, from the very commencement of their flight, to fall below what would have been the trajectory of the shell had it not burst; and had they to travel any considerable space, their fall would be large. Practically, however, the distances in front of objects at which shrapnel are as a rule burst, are small, and the fall of the centre line of the cone below that of the trajectory of a shell is insignificant. Lieut. Goold-Adams has been good enough to place at the writer's disposal the accompanying diagrams (Figs. I., II., III., IV., V.) of the cones of dispersion of different shrapnel shells at different ranges. Taking any two as an example, it will be seen that at 900 yds. range the centre line of the cone of a shell burst 150 yds. short falls only 1½ ft. below the trajectory of the shell; at 2000 yds. and 80 yds. short, only 2 ft. Practically, when the cone is so large, so small a fall can affect the general result but slightly.

If, then, it is conceded that the angles of the cones for different ranges as given above are fairly correct, and that practically we may take the centre of the cone to coincide very nearly with the trajectory of the shell, the effect of shrapnel due to different ranges and lengths of burst may be easily calculated.

We shall have to consider, with regard to this cone of dispersion—

1. Its diameter at different parts, and the breadth of ground which it consequently covers.
2. Its area at different lengths, and the number of bullets and splinters in such area.
3. Plan of ground covered by effective fire, especially with regard to the length from front to rear.
4. Effect of height of burst above plane.
5. Power of bullets at different distances from burst, when the shell is travelling with different velocities.

Having considered these points, it will be possible to deduce the best positions at which to burst shells with a view to the work they may be required to perform.

1. The diameters of the cone for different angles will be, speaking roughly, as follows :—

For 8°	·14 of the length.
" 9°	·15 "
" 10°	·17 "

The following table may be of use; it represents the fronts covered laterally by various cones at various lengths from the point of burst:—

TABLE II.

Length from Burst in yards.

	20 yds.	40 yds.	60 yds.	80 yds.	100 yds.	120 yds.	140 yds.	160 yds.	180 yds.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
8°.....	8·4	16·8	25·2	33·6	42·0	50·4	58·8	67·2	75·6
9°.....	9·3	18·6	27·9	37·2	46·5	55·8	65·1	74·4	83·7
10°.....	10·5	21·0	31·5	42·0	52·5	63·0	73·5	84·0	94·5

As a general rule, it would be quite near enough to say that for ordinary ranges the cone of dispersion is from 8° to 9° and the diameter from ·14 to ·15 the length from burst of shell.

2. The area of a section at right angles to the central line of the cone is the space which the splinters and bullets spread themselves over at the different portions of their flight; and since the chief cause of the spread—viz., the centrifugal force imparted by the rotation of the shell—affects these bodies in a degree differing with their distance from the centre of rotation, they are spread with very fair regularity over this space.

Taking one of the angles just mentioned as those due to ordinary ranges—viz., 8°—the following will be the square yards of area in the cone at different lengths of burst:—

TABLE III.

Length of Burst in yards.

	20 yds.	40 yds.	60 yds.	80 yds.	100 yds.	120 yds.	140 yds.	160 yds.	180 yds.	200 yds.
	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.
8°	6	24	55	98	154	222	302	394	498	615

When a 9-pr. M.L. shrapnel shell is burst at rest, the following is the average result:—

Splinters, effective	22
" non-effective	6
Bullets	63
Effective total	85

In the case of a 16-pr. M.L. shrapnel,

Splinters, effective	13
" non-effective	3
Bullets	123
Effective total	136

The following will therefore be the number per square foot at the different areas, as above stated:—

TABLE IV.

Length of Burst in yards.

Guns.	20 yds.	40 yds.	60 yds.	80 yds.	100 yds.	120 yds.	140 yds.	160 yds.	180 yds.	200 yds.
	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.
9-pr.	1·6	·4	·17	·1	·06	·043	·03	·024	·02	·015
16-pr.	2·5	·62	·26	·15	·1	·07	·05	·04	·03	·024

If now the area of the upright figure of a man is taken, it will be found that, if these tables are correct, when a shell is burst 20 yds. short of a line, each man in the area covered by its fire is hit, in the case of a 9-pr. by nearly 16, and of a 16-pr. by nearly 25 bullets. These are direct hits, and do not take into account the bullets of the lower portion of the cone which ricochets.

Here is a manifest waste of power: our object must naturally be not to disable one man by 16 or 25 hits, but 16 or 25 men by one hit each.

In fact, the practical question to be solved at this point is—What is the distance at which a shrapnel shell ought to be burst in front of a body of troops with an extended front, so as to have the best chance of disabling the largest number possible?

Combining the calculations we have already made with the practical experience of the experiments at Shoeburyness (Table I.), the following may be said to be the results at different lengths. Throughout, the effect on the front row only is taken into account, and the number of hits shown in the Report has been reduced by $\frac{1}{3}$, to allow for the difference between a 9-ft. and 6-ft. target.

At 800 yds. range:—

Length of burst, 50 yds. short.
Spread of cone (see Table II.) = 7 yds.
Area of target covered, $7 \times 3 \times 6 = 126$ sq. ft.
No. of men in area $\frac{7 \times 3 \times 12}{21} = 12$.

Taking the number of direct hits for this area and length of burst from Table IV., they will be $126 \times \cdot44 = 54$. At such a range they would doubtless be all throughs. One-third the average number of throughs in the Report = 63; the balance, after deducting the direct hits, is therefore $63 - 54 = 9$, and these are due to ricochet.

Under the conditions, the whole of the lodges may be taken as effective bullets. They are the result of ricochet, and to it therefore $9 + 15 = 24$ effective hits may be credited.

Now, the whole number of pieces in the shell is 136, and deducting

from this the direct hits (54), the result will give 82 as the number of pieces which would have passed half over and half under—the latter, of course, at such an angle of descent, and on good ground such as that on which the targets were placed (very hard smooth grass), ricochetting. We may therefore infer that $\frac{24}{41}$, or rather more than $\frac{1}{2}$, of the lower portion of the cone was effective on ricochet.

The total number of lodges and throughs is 78 per round, and this gives 6·5 bullets per man in the area of the target. It may fairly be supposed that each was hit at least twice, and would therefore count as two disabled, giving a total of 24. The average from the practice Report (Table I.) is 22. It may, however, be observed that the 2nd round gives a very unsatisfactory return—only 16 men to 66 throughs—a fact most probably due to the shell holding together, and not distributing its bullets as usual. Eliminating this round, the average is 23·5, or as nearly as possible 24.

At 100 yds. burst:—

Area = 252 sq. ft.
Men in do. = 24.
Direct hits (Table IV.) = 252 × ·1 = 25·2.
Average of throughs (Table II.) = 25·2.
Throughs due to ricochet = 0.
Lodges " " = 15.
Throughs and lodges due to ricochet = 15.

$$\text{Lower part of cone ricochetting} = \frac{136 - 25}{2} = 55.$$

$\frac{15}{55}$, or $\frac{1}{4}$ nearly, of this part of the cone, therefore, gave effective ricochet.

The whole number of bullets in area = 40. Each man has therefore an average of $1\frac{2}{3}$; but as the men do not occupy the whole area of the target, each cannot have been struck by so many. The average at this distance of burst in Table I. is 25—one more only than the number in the area.

It will be remarked that the ricochet is rapidly losing power; the proportion of lodges to throughs is increasing very rapidly.

At 150 yds. burst:—

Area = 378 sq. ft.
Men = 36.
Direct hits = 13·6.

The throughs are only 12, and a certain proportion (13·6 − 12 = 1·6) even of the direct hits are now only lodges.

Lodges due to ricochet = 11 − 1·6 = 9·4.

$$\text{Lower portion of cone ricochetting} = \frac{136 - 14}{2} = 62.$$

$\frac{9\cdot4}{62}$, or between $\frac{1}{6}$ and $\frac{1}{7}$ of the cone, is effective.

The total number of bullets in area = 23. Each man has an

average of ·64 bullets; all cannot have been hit. The practice Report gives an average of 19 casualties out of the 36 men in the area.

At 200 yds. burst:—

Area = 504 sq. ft.
Men = 48.
Direct hits = 12.
Throughs = $4\frac{1}{2}$.
Lodges = 9.
Balance of lodges and throughs due to ricochet = $1\frac{1}{2}$.
Lower portion of cone ricochetting $\frac{136 - 12}{2} = 62$.

$\frac{1 \cdot 5}{6 \, 2}$, or $\frac{1}{41}$ part of the cone, is effective.
The hits per man are ·28, and only a small number are disabled; the average is 10.

It may be remarked of the practice from which these results are taken, that the height of burst above plane is often considerably below what the path of the shell should have been had the centre of the target been aimed at, and this more in the longer than in the shorter bursts. The results are therefore not altogether trustworthy, especially in regard to the amount of ricochet.
The effects produced by different lengths of burst may be tabulated as follows. (Range, 800 yds.):—

Burst short.	Direct hits.	Ricochet.	Proportion of bullets effective on ricochet.	Men disabled.
50 yds.	54	24	$\frac{1}{2}$	22
100 "	25	15	$\frac{1}{4}$	25
150 "	14	9	$\frac{1}{7}$	17·4
200 "	12	2	$\frac{1}{41}$	10

At 1500 yds. range only two lengths of burst were tried—viz., 50 yds. and 150 yds.
At the 50 yds. burst the result cannot be satisfactory; for notwithstanding the larger angle of descent due to the increased range, the heights above plane are even smaller than at 800 yds. range. The only rounds at all near the truth are the two last. Taking the averages from these two—

As before, Area = 126 sq. ft.
Men = 12.
Direct hits = 54.
Throughs = 63.
" due to ricochet = 9
Lodges " " = 8 } = 17.
As before, Lower half of cone = 41.

$\frac{17}{41}$, or $\frac{2}{5}$, are effective on ricochet.
Average of bullets per man = 6 nearly. Men disabled, 20.

At 150 yds. burst:—

Men = 36.
Direct hits = 13·6.
Throughs = 11.
Lodges = 10.
Lodges due to ricochet = 7·5.
Lower half of cone = 61.

$\frac{7 \cdot 5}{61}$, or $\frac{1}{8}$, are effective.
Hits per man = ·58. Men disabled, 19.

This result, compared with the same burst at 800 yds. range, seems strange. It may be attributed to the bad round (No. 5) at the 800 yds. range, to the exceptional luck of all the rounds—especially Nos. 3 and 5—at the 1500 yds. range, and the favourable state of the ground for ricochet.

Tabulating the averages, we have—

Burst short.	Direct hits.	Ricochet.	Proportion of ricochet to ½ cone.	Men disabled.
50 yds.	54	17	$\frac{2}{5}$	20
150 "	14	7	$\frac{1}{8}$	19

The closeness of these results to those at the 800 yds. range is very remarkable.

It may fairly be objected that there are some points about the practice which would render it necessary to be careful in depending too entirely on the conclusions drawn from them. The following may, for example, be urged:—

1. That only five rounds for each range is too small a number.
2. That such points as the height above plane were not very carefully made.
3. That the screen was thick enough to retard and disturb the flight of the shell.
4. That counting two men when one dummy is hit twice, and taking no account of a larger number of hits, is in many ways misleading.

Though these facts cannot be gainsaid, it may be urged that the results obtained are sufficiently equal to allow of their being taken as very near the truth.

From what has thus been deduced from practice it would seem that with the 16-pr. M.L. gun at 800 yds. range, the best point for bursting a shrapnel shell, if an extended front has to be covered, is 100 yds. short; and from Table IV. we find that the amount of bullets per square foot of area is, at this distance, ·1. The distance for the 9-pr., which gives the same proportion of bullets, is 80 yds., and this may therefore be supposed to be the best distance for its burst.

At longer ranges than 800 yds. it will be necessary to burst shrapnel closer; because (1) the velocity of the bullets due to that of the shell becomes lower, and their power is therefore smaller; (2) the angle

of descent becomes greater, and the ricochet is consequently less effective; (3) the angle of the cone of dispersion increasing, it is not so necessary to be so far back to obtain the same amount of spread on the object; (4) as the angle of descent becomes larger, the amount of ground covered by the cone in the direction of the range is smaller; (5) as the velocity of the bullets becomes smaller, they tend to fall proportionately further below the trajectory of the shell.

The following distances of burst may, it is believed, be safely proposed as the best for objects with an extended front:—

		Yards short.	Front covered.
16-pr. ...	Under 1000 yds. range	100 ...	42·0 ft.
	From " to 2000 yds. range ...	80 ...	33·6 "
	" 2000 yds. to 3000 " ...	60 ...	25·2 "
	Above this range.....	50 ...	21·0 "
9-pr. ...	Under 1000 yds. range	80 ...	33·6 "
	From " to 2000 yds. range ...	60 ...	25·2 "
	" 2000 yds. to 3000 " ...	40 ...	16·8 "
	Above this range.....	30 ...	12·6 "

This power of spreading the effect, the value of which need hardly be insisted upon, is peculiar to shrapnel with time fuzes only, as will be shown further on.

3. The plans of the ground covered by an effective fire in the case of the two lengths of burst of the shell shown in Fig. V., are shown in Figs. VI. and VII. The distances covered from front to rear in the different lengths of range and burst shown in Figs. I., II., III., IV., and V., are as follows:—

Range.	Burst short.	From target.		Total ground covered.
		First strike in front.	Last strike in rear.	
yds.	yds.	yds.	yds.	yds.
1000	150	82	330	410
"	100*	52	300	352
"	100†	58	282	340
2000	100	42	127	171
"	80	35	120	155
2500	100	36	100	136
"	60	22	73	95

* Laid for centre of target. † Laid for bottom of target.

That these distances are covered in practice may be inferred from the experiment recorded at p. 16 Okehampton Report. Here a battery of 16-prs. was in action against two lines of 100 dummies each, one 1000 yds. the other 1210 yds. distant from it. 35 rounds of shell were fired, which were burst on the average about 100 yds. short of the

front line—none were burst within 20 yds. short; none over. Their heights above plane were those due to the elevation for the first line—viz., 1000 yds. The result was 71 dummies disabled in the first line, 24 in the second. In other words, notwithstanding the shells having been burst low for the second line, the number disabled in it show that a distance of 268 yds.* had been covered with an effective fire; and as many of them had been hit high up, a still longer range was evidently attained by some of the bullets.

The peculiar form of the plans in Figs. VI. and VII. will show—

(1) That where the object has depth, the fire cannot be too direct.

(2) That where the object has width and little depth, the more oblique the angle of fire is to the front, the greater is the area affected.

(3) That time shrapnel is peculiarly adapted to objects moving towards or from the battery. If in the first case the fuzes are bored rather short, in the second rather long, the amount of ground covered will compensate for very considerable errors due to incorrect estimation of range or movement of object.

4. It has already been advanced that the fall of the centre of the cone of dispersion below what would have been the trajectory of the shell had it not burst, is comparatively small. From the plans of the ground covered by fire in the previous paragraph, it will be seen that at the point where the centre line of the cone cuts the ground line is the greatest spread of direct hits by those bullets which have not ricochetted. It would appear, therefore, that to obtain the greatest effect on a vertical target, the gun should be laid with an elevation giving a striking point just above the centre. Is this the fact in practice?

In the Shoeburyness Report, Table I., already referred to, taking the series at 800 yds. range, burst 50 yds. short, the best shell is one burst 9 ft. above plane; if we take the whole number of hits, the next best is $6\frac{1}{2}$ ft. above, and the worst $5\frac{1}{2}$ ft. In Fig. I. the height of the trajectory shown at 50 yds. from the target is 9·56 ft., and it is to this height that the best shell has most nearly approached. Where the differences of height above plane are so small as they were in general throughout this practice, the amounts by which the effect of these differences will be shown must be small; indeed a certain amount of luck in a shell will even at times have the effect of making the wrong height appear the best, especially when the conditions are so favourable to shells bursting low as they were in the instance under consideration, when, the ground being exceedingly hard and smooth, the ricochet was consequently very effective. The record of the 50 yds. short at 1500 yds. will, however, show very clearly the loss occasioned by bursting the shell too low.

Since this practice seems to confirm the conclusions drawn above, the

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* 58 yds. in front (see table), and 210 yds. distance between targets.

following table of the best heights above plane for the 9-pr. and 16-pr. M.L. at different ranges will be of use:—

16-pr.				9-pr.		
Burst short.	Range.	Angle of descent.	Height.	Burst short.	Angle of descent.	Height.
yds.	yds.	° ′	ft.	yds.	° ′	ft.
100	1000	2 20	12·0	80	2 29	10·4
80	1200	3 0	12·6	60	3 10	9·9
"	1400	3 40	15·3	"	3 54	12·2
"	1600	4 25	18·5	"	4 43	14·8
"	1800	5 12	21·9	"	5 38	17·9
"	2000	6 0	25·0	"	6 37	21·0
60	2200	6 57	21·6	40	7 39	16·0
"	2400	7 47	24·5	"	8 46	18·5
"	2600	8 45	27·7	"	9 54	20·9
"	2800	9 45	30·8	"	11 10	23·6
"	3000	10 46	34·2	"	12 34	26 5
50	3200	11 47	31·2	30	13 53	22·2
"	3400	12 46	33·9	"	15 22	24·6
"	3600	13 51	36·7	"	17 6	27·6
"	3800	14 52	39·7	"	18 50	30·7

The loss due to errors in height above plane may be seen from the following cases.

Suppose the targets shown in Fig. VIII. to be a front elevation of the section in Fig. II. The circle whose centre is at *A* will represent a section of the cone of dispersion of the shell burst 100 yds. short, and those portions which give direct hits, or pass over or under; the circle having its centre at *B* will represent a shell burst at the same distance, but 10 ft. higher; that at *C*, one 10 ft. lower. In Fig. IX. the same is shown in the case of a shell 50 yds. short, burst (*A*) in the proper trajectory, (*B*) 10 ft. higher than it, and (*C*) on plane.

Though these losses are considerable, they are by no means so great as to make any of the shells inefficient, and they are quite the outside of the amount that should be due to ordinary errors of laying. As may be seen from the Shoeburyness practice, small errors in this direction do not entail much loss, although, of course, to obtain maximum effects they must be carefully avoided.

When a shell bursts too high or too low, it must not be at once decided that the gun is badly laid; it may be due simply to the faulty boring or incorrect burning of the fuze. If any doubt should arise as to where the fault lies, a shell with percussion fuze will soon set the matter at rest; it will show at once whether the estimated range is correct, or—what is the same thing in practice—whether the gun is throwing under or over the object. If either is the case, the laying must be corrected; if neither, the fault is evidently due to the fuze. If the burst is too high, the shell is bursting short and the fuze must be lengthened; if too low, it requires shortening.

5. The question of the power of the bullets at decreasing velocities is one of vital importance to the elucidation of the subject. What is the lowest velocity at which they are effective? In some French

experiments, it was, I believe, found that a bullet which buried itself half its diameter in a deal board would penetrate a dead horse. In some English experiments, of which I regret that I cannot find an account, the lowest effective velocity has been stated at about 400 f.s. In default of any data sufficiently precise, however, the lowest velocity might perhaps be put at 500 f.s. without much fear of its being too small.

The targets usually fired at are 2-in. deal, as used in the Shoeburyness experiments. Throughs are certainly effective bullets; lodges may or may not be, but the majority no doubt are; strikes may or may not be, but the great majority certainly are not. As a rule, therefore, in this paper lodges have been taken into account, strikes have not.

The velocity of the bullets depends, at the commencement of, and consequently throughout, their flight, upon the velocity of the shell at the moment of opening; and this may have fallen very low from

a. Long range.
b. Retardation from ricochet.

When once they have parted from the shell, their velocity is affected by

c. Resistance of the air.
d. Retardation from ricochet.

We may expect, therefore, to find in actual practice that the bullets lose in power—

(1) As the range increases.
(2) When the shell bursts after ricochet, or on graze.
(3) As the point of burst is farther from the object.
(4) As more of the hits are due to ricochet of the lower half of the cone of dispersion.

(1) At first sight it would appear that the best method of proving this fact would be by contrasting the proportion of strikes and lodges to throughs at differing ranges. In doing so, however, there would be this difficulty: at the shorter ranges the number of bullets which ricochet is comparatively very large, and—as will afterwards be shown—the retardation due to this cause being very considerable, it would increase the proportion to an undue extent. To show it perfectly it would be necessary to have ground on which no ricochet could take place, and this has never been the case.

We have, in the practice at Shoeburyness and Okehampton, 16-pr. R.M.L. shrapnel fired at 800, 1500, 2000, 3450, and 3970 yds., and these we will attempt to contrast where the results are sufficiently reliable.

At the 800 yds. range, only the 150, 100, and 50 yds. bursts are taken; those at 200 are omitted, as being beyond the limit of fair shell.

At 1500 yds., the two first rounds of the 50 yds. burst are omitted, as the heights above plane are very bad.

The effect upon the first row of targets only will be considered; since on the others many strikes and lodges might be due to bullets which, having already passed through targets, were unduly retarded. As unfortunately there were no hits on the front target at the 3450 yds. range at Okehampton, it cannot be taken into account.

As there were only two effective shell at the 3970 yds. range, the results are not very reliable; still they serve to show that a considerable loss of power does undoubtedly take place.

The following table gives the proportion of strikes and lodges to throughs:—

Range.	Strikes and lodges.	Throughs.
800	1	2·7
1500	1	1·9
2000	1	0·46
3970	1	0·03

The contrast here presented is sufficiently striking. Another, however, may be afforded by showing the number of dummies disabled per shell. As the heights above plane are not given in the case of the last two ranges, only one-half of the shells bursting in front will be taken as effective. Even with this allowance, the result will be—

Range. yds.	Dummies disabled, per shell.
800	18·2
1500	16·1
2000	5·4
3970	1·0

(2) It is comparatively easy to show the loss of power due to shells being burst on graze, or immediately after it.

In the Okehampton Report, p. 68, two half-batteries were practising at similar targets under precisely similar circumstances, one using percussion and the other time fuzes. In the former case all the shells must have been burst on graze, or immediately after it; in the latter, all were burst in the air. The following are the proportions of strikes and lodges to throughs per shell:—

	Strikes.	Lodges.	Throughs.
After graze	0·93	5·5	1·4
Before "	1·0	1·7	4·0

or, taking strikes and lodges together, the proportion they bear to the throughs is:—

After graze	4·6 to 1
Before "	0·675 to 1

In a word the bullets have, if this is taken as a measure of their power, about seven times as much in the latter as in the former case.

(3) The loss of power due to the distance at which the shells are burst from the object may be seen by contrasting those in the Shoeburyness experiments. Taking the 800 yds. range, the following are

the strikes, lodges, and throughs per shell at different distances of burst:—

yds.	Strikes.	Lodges.	Throughs.
50	4·4	6·6	9½·2
100	1·8	23·2	32·6
150	0·2	16·4	16·0
200	1·4	13·6	6·4

and the proportion of lodges and strikes to throughs is therefore at

yds.	
50	1 to 8·56
100	1 to 1·3
150	1 to 0·96
200	1 to 0·42

Their power is, in fact, rapidly diminishing.

(4) It is difficult to show precisely the loss of power experienced by the bullets which ricochet. Since, however, the lower the burst of the shell the greater is the amount of ricochet, we may attempt to do so by taking the lower bursts and contrasting them with the highest in each series of the 800 yds. range in Table I. Only three are considered, as the differences at the 200 yds. are too small. The following figures show the proportion of strikes and lodges to throughs:—

Burst. yds.	Height. ft.	Strikes and lodges.	Throughs.
50	5½*	0·15	1
	Average of remainder	0·077	1
100	8¼	1·2	1
	Average of remainder	0·67	1
150	9†	1·25	1
	Average of remainder	0·95	1

From this it will be seen that as the amount of ricochet increases the power decreases; and that notwithstanding the fact that the lower burst is favourable to the power of ricochet.

These figures do not show the fact in a very striking manner, since the difference between the heights is but small. They are, however, sufficiently significant, especially when it is remembered that the ground in this practice was admirably adapted for rendering ricochet effective.

Percussion Shrapnel.

When shrapnel is used with percussion fuzes, the result is of necessity wholly different from that which has been considered in the preceding remarks. The opening of the shell and the consequent cone of dispersion remain, of course, the same, but take place under different conditions.

With a time fuze, the shell opens in the trajectory before graze,

* Average of three. † Average of two.

having therefore (*a*) a descending angle, and (*b*) a velocity impaired only by the resistance of the air.

With a percussion fuze, it opens after graze, having (1) an ascending angle, and (2) a velocity considerably impaired, in addition, by the retardation on graze.

(1) When a percussion shrapnel is burst through a 2-in. screen, it will be seen that the action takes place from 6 to 9 ft. beyond it. Graze on ordinary ground retards the shell more and causes a slightly quicker action of the fuze; the difference is, however, but slight, and the shell will be observed to act from 2 to 3 ft. after rising. It must therefore have at the time an angle of ascent instead of one of descent.

The angle at which the shell rises after graze has never been carefully ascertained; the writer has, however, observed a certain number of shell with time fuzes which burst, or struck targets after graze. Although the number and the care of the observations is hardly sufficient to warrant him in speaking conclusively on the subject, he believes that he is well within compass when he assumes roughly that with descending angles of less than 6° the angle of ascent is about one-fourth, and over 6° about one-third more.

This angle of ascent would of course differ with a variety of conditions; the consistency of the ground and the inclination of its plane being the two most important factors.

With regard to the first, it is evident how great uncertainty in practice must be caused by it, even when the nature of the ground on which the object stands is well known; when—as must very often be the case—it can only be guessed at, this uncertainty is immensely increased.

The second would also greatly affect the regularity of practice. Suppose, for instance, the angle of descent to be 6° on level ground of ordinary consistency; that of ascent would be at least 8°. If the ground had a slope of 2° to the front, the angle of impact would be 4° to the slope, and that of ascent 6° to the slope and 4° to the horizontal plane. With a slope of 2° in the opposite direction, the angle of descent would be 8° to the ground, that of ascent 10° 40′ to the ground and 12° 40′ to the horizontal plane. A small undulation of ground is sufficient to produce such an effect, and—as will be shown further on—the result would seriously affect the practice.

(2) The retardation, and consequent loss of power, due to ricochet has already been shown (p. 187), and need not be further insisted upon here.

The relative position of the cone of dispersion to the path of the shell has also been described (p. 177); it will, of course, be the same whether the angle is ascending or descending.

The ascending angle has the following effect: (1) the centre of the cone rises; (2) many—in some cases the whole—of the bullets start with an elevation.

(1) The trajectory of the shell after graze is most difficult to describe

with great accuracy, since the retardation is not correctly ascertained. The following table of the heights of the trajectories at successive points will, however, give a sufficient approximation to the truth. With it is given the semi-diameter of the section of the cone of dispersion at the different lengths of burst (so that the position of the lowest bullet of the cone can be seen), and the number of men that would be covered by its fire.

Range.	Angle of ascent.	10 yds.	15 yds.	20 yds.	30 yds.	40 yds.	50 yds.	60 yds.	70 yds.	80 yds.	90 yds.	100 yds.	120 yds.
yds.	degs.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1000	2·55	1·4	2·1	2·8	4·2	5·5	6·9	8·2	9·4	10·6	11·7	12·8	14·8
1300	4·9	1·9	3·0	4·1	6·2	8·2	10·1	12·0	13·9	15·8	17·6	19·4	21·1
1600	5·31	2·6	4·0	5·4	7·9	10·5	13·0	15·5	18·0	20·3	22·6	24·9	27·1
2000	8·0	4·0	5·9	7·8	11·6	15·4	19·1	22·8	26·3	29·6	32·6	35·4	38·0
2300	9·45	5·0	7·3	9·5	14·2	18·8	23·3	27·9	—	—	—	—	—
2600	11·40	5·8	8·7	11·5	17·1	22·6	28·0	33·3	—	—	—	—	—
3000	14·20	6·8	10·2	13·5	20·1	26·6	33·0	39·2	—	—	—	—	—
Radius of cone of dispersion ...	.....	4·1	2·6	4·2	6·3	8·4	10·5	12·6	14·7	16·8	18·9	21·0	23·1
No. of men covered ...	.....	3	4	5	8	10	12	15	17	20	22	24	27

With the aid of this table it may easily be seen how large a portion of the useful effect of shrapnel is lost when burst after graze.

For instance, at 1000 yds. range, if a percussion shell grazes 50 yds. short, the centre of the cone of dispersion passes ·9 ft. over the top of a 6-ft. target, and at 100 yds. 6·8 ft. above it. At this latter distance, the semi-diameter of the cone is 21 ft. In Fig. IX. a time and percussion shrapnel burst at this latter distance are contrasted. The target is 56 ft. × 6 ft. The circle whose centre is *A* (6·8 ft. above the top of the target) represents a percussion shell grazing 100 yds. short; *B* the centre of the cone of a time shrapnel, burst 100 yds. short, coinciding with the centre of the target. The portions which pass over, hit direct, and afford ricochet are shown by the portions of the circles above, on, and below the target. Here the loss of effect due to the use of a percussion fuze is considerable, mainly from the absence of effective ricochet.

At 1300 yds. range, the best length of burst for a 16-pr. R.M.L. shell with a time fuze has been given as 80 yds.

The circle whose centre is at *A* (Fig. X.) represents a percussion, that at *B* a time shrapnel, burst at this distance. The dotted lines showing an arc on the target with the centre at *C* represent a percussion shell, and those with the centre at *B* a time shell, burst 120 yds. short. The loss with the former becomes gradually greater as the range increases.

To obtain anything like similarity of effect between a percussion and

time shell they would have to be burst much closer. In Fig. XI. *A* is a percussion, *B* a time shrapnel, burst 30 yds. short, at 1600 yds. range. Here the areas affected are not very dissimilar, but the amount is still in favour of the time fuze; and although this last has the advantage of affording ricochet, which is entirely wanting with the percussion, yet since at such a length of burst the bullets lie very close together, it is not absolutely required to ensure such an effect on the target as to make certain of hitting every man in the area. In a word, the effects are fairly equal. But to obtain this similarity of effect, spread on the target has been given up to a serious extent. The percussion shell 30 yds. short only embraces a front of 9 men, whereas the time at 80 yds. would cover 20. If both were burst at 80 yds., however, a percussion shell would, compared with a time, lose far more in proportion; for here the area of target it covers is comparatively much smaller, and while the distribution of the bullets has increased, the ricochet (which is therefore more than ever necessary) is wanting. At 120 yds. the disproportion would be even more marked.

In Fig. XI.a, the two circles *A* and *B* contrast the effect of a percussion and time shell at 1600 yds. range, burst 40 yds. short; *CD, EF,* 100 yds. short. Here the difference between the two becomes still greater.

At 2000 yds. range, a percussion shell 30 yds. short would only just touch the top of the target with the very lowest bullets of the cone, and 40 yds. short would miss it altogether. At 2300 yds. it would only just touch at 20 yds., and miss at 30 yds. At 2600 yds. it would miss altogether at 20yds., and at 3000 yds. at 15 yds. short.

The loss sustained by using percussion fuzes may be very clearly shown by contrasting the number of bullets in an area of target such as that shown in Fig. XI.a. Range, 1600 yds.; shell burst, 40 yds. short.

Time Fuze.

	Area affected. sq. ft.	Bullets.
Direct hits	99	61
$\frac{1}{3}$ of ricochet	—	7
	99	68

Percussion Fuze.

	Area affected. sq. ft.	Bullets.
Direct hits	39	24

There is, of course, no ricochet with the percussion shell.

In the former case, not only is the proportion of bullets to area (·68 per sq. ft.) rather more than in the latter (·64 per sq. ft.), but the difference of area affected is about $2\frac{1}{2}$ times greater.

It may be assumed that if the height of the target is 6 ft., a percussion shell whose centre of cone passed about 1 ft. from its top would produce the maximum effect.

If this assumption is correct, the following table will give the best distances at which to burst percussion shrapnel for a few different ranges, and the number of men covered by shells so burst. The third

column will give the number covered by the most effective time shrapnel at the same ranges.

Range.	Distance.	No. of men covered.	No. of men covered by time shrapnel.
yds.	yds.		
1000	40	10	24
1300	25	7	20
1600	20	5	20
2000	12	4	20
2300	10	3	15
2600	9	3	15
3000	7	2	15

This small spread not only leads, as thus shown, to a very considerable loss of effect, but it enhances the difficulty of making good practice, since any errors in a lateral direction become serious. Take, for instance, a range of 1600 yds. The best distance for a percussion shrapnel is 20 yds. short, and the diameter of the cone is 8·4 ft.; if the shell is 4 ft. right or left, one-half, and if 8·5 ft., the whole of the effect is lost. With a time shrapnel burst at its best distance neither of these errors would seriously matter, since the cone is 33·5 ft. in diameter.

The following tables will show how much more difficult is the use of percussion than time shrapnel, as far as mere accuracy of shooting is concerned. They give the limits within which either nature is effective.

Percussion shrapnel.				Time shrapnel.			
Ranges.	Burst short.			Ranges.	Burst short.		
	Effective.	Good.	Bad.		Effective.	Good.	Bad.
yds.				yds.			
1000	from 20 to 100	40	over 170	1000	from 10 to 150	100	over 250
1300	„ 20 to 70	25	„ 145	1300	„ 10 to 120	80	„ 220
1600	„ 15 to 50	20	„ 100	1600	„ 10 to 110	80	„ 190
2000	„ 10 to 25	12	„ 50	2000	„ 10 to 100	80	„ 170
2300	„ 5 to 15	10	„ 30	2300	„ 10 to 90	60	„ 150
2600	„ 5 to 12	9	„ 20	2600	„ 10 to 85	60	„ 135
3000	„ 5 to 10	7	„ 15	3000	„ 10 to 80	60	„ 120

The existence of this increased difficulty of using percussion shell in comparison with time may be admitted, and yet it may with justice be urged that after all it may more easily be overcome than those incidental to correctly boring time fuzes, and estimating with certainty the effect produced by their bursts—the former of which does not exist when percussion fuzes are used, and the latter only to a modified extent. Such is undoubtedly the case; still, when fire is deliberate (as it always should be, except under very exceptional circumstances), when N.C.O.'s and men are properly instructed, and the supervision of officers is judiciously exercised, these difficulties, although they can never wholly disappear, are reduced to a minimum, and the superiority of time over percussion shells rarely fails to assert itself.

The practice recorded at pp. 6 and 7 Okehampton Report may be cited in confirmation of this view. The effective shells are given for each 18 rounds fired.

	Range. yds.	Effective out of 18 rounds. Time fuze.	Percussion fuze.
9-pr.	1500	15	12*
	2100	17	14*
16-pr.	1500	18	12*
	2100	14	15*

With respect to these, it must be remarked that any percussion shell which burst in front is called effective, whereas a certain number burst 150, 140, 120, and 100 yds. short could therefore hardly have been said to be so at such ranges.

When time were pitted against percussion shells at practical targets, such as dummies in formation of attack, the superiority of the former is very marked. The following table is compiled from the Okehampton Report, pp. 6–8 :—

	Range. yds.	Dummies disabled. Time fuze.	Percussion fuze.
9-pr.	1500	38	13
	2100	33	21
	2950	72	22
		143	56
16-pr.	1500	57	21
	2100	37	14
	2950	109	84
		203	119

The practice with the 9-pr. R.M.L., Series O. and P., Okehampton Report, p. 68, already referred to at p. 187 of this paper, is not here considered, because it gives only hits and not men disabled, and (as

* Average of 3 series of 18 each.

has already been shown) these former alone are no criterion of good or bad shooting.

Nor are the long ranges from p. 72 to 80 of the Okehampton Report taken into consideration, because (1), the time fuzes were entirely experimental; (2), because the form of the targets (large, 9 ft. × 9 ft., placed close together) was unpractical, and gave an immense advantage to percussion fuzes, which in many cases burst through one of them, and thus imitated the action of time fuzes on those immediately in rear; (3), because strikes are taken into consideration in estimating troopers disabled. For instance (p. 75), 1st Squadron, rear rank, through 1, struck 12, disabled 6. It is hardly possible that a bullet which would only make a graze on soft deal could disable anyone.

(2) The amount of ground covered in the direction of the range by time shrapnel has already been shown (p. 183). It may be as well to draw attention a little more closely to Figs. I. to V., where the trajectories of time shrapnel at 1000, 2000, and 2500 yds. are given in detail. The following table will show with what angle the lowest and highest bullets of the cone start, and their remaining velocity on reaching the ground; the height above plane is also shown. From it may be gathered whether the ground is actually covered by effective fire.

Range.	Burst.		Lowest bullet.		Highest bullet.		Ground covered.
	Distance.	Height.	Angle of ascent.	R. V.	Angle of ascent or descent.	R. V.	
yds.	yds.	ft.	° ′	f.s.	° ′	f.s.	yds.
1000	100	10	5 50	930	2 10 asc.	410	349
2000	180	32	14 32	770	1 0 desc.	550	171
"	80	25	"	786	"	580	155
2500	100	43	17 20	730	3 5	556	136
"	60	25	"	760	"	650	95

It will be seen that the only bullet which started with elevation (the highest of the cone at 1000 yds.), although its initial velocity was the highest, lost a larger portion than any of the others, and at the end of its trajectory had the lowest velocity of all—only 440 f.s. remaining, one hardly sufficient for effect. From this it might fairly be urged that any bullet of a percussion shell starting with the impaired velocity of a shell after graze, and with an elevation of 2° 50′, would have so little momentum before it reached the ground as to be to all intents and purposes harmless. Taking, however, into consideration the fact that with objects 6 ft. in height the bullets would have become effective before they actually reached the ground, it may be asserted that 5° is the highest angle of elevation at which a bullet, even at short ranges, would retain sufficient striking velocity. With percussion shell, consequently, unless they are burst sufficiently near for the bullets to

strike the object in the early portion of their flight, before they have attained a height of 6 ft., the following proportion of the cone is lost:—

At	1000 yds.	range the	loss =	·184 of the cone.
"	1300	"	" =	·36 "
"	1600	"	" =	·56 "
"	2000	"	" =	·92 "

In the case of time shrapnel, although at long ranges the bullets may start on the opening of the shell with comparatively small velocities, yet, in consequence of the greater angle of descent, they have but a short range, and consequently retaining a very sufficient velocity, the whole of the cones are composed of effective missiles.

In the case of percussion shrapnel the velocity of the shell decreases as the range increases, in the same manner as with time; but here the analogy between them ceases. Not only are the bullets affected by this loss, but also by retardation on graze; although, since they start at a larger angle of elevation, they require more instead of less velocity to render them effective as they progress. Both these causes of loss increase rapidly with the range and the consequently larger angles of descent and ascent.

If these facts are taken in conjunction with those at p. 194, it is evident how soon percussion shrapnel cease to be effective from the bullets rising, and how few of these latter, even at ordinary ranges, still retain sufficient momentum when they have descended low enough to come again into play. In other words, the ground covered by percussion compared with time shrapnel is very small, and decreases rapidly as the range increases.

When an obstacle, either natural or artificial, is interposed between a percussion shrapnel and the object, the amount of loss of effect is very great.

Take, for instance, the parapet of the gun pit in the Okehampton experiments. It was 3 ft. high and the pit 2 ft. 6 ins. deep. A man of 6 ft., standing upright, had therefore only 6 ins. exposed to fire. When loading, the Nos. were placed in the ordinary position. Nos. 2 and 3 were 5·5 ft., 4 and 5 11 ft. behind the parapet. A 16-pr. R.M.L. was employed. The range was 2030 yds., and the angle of ascent of its percussion shell, therefore, was about 8°.

The following table will give the portions of the men exposed to bullets in such a case:—

Burst.	Nos. 2 and 3.	Nos. 4, 5, and 1.
10 yds. ...	passes clear	passes clear.
20 "	·125 ft.	"
30 "	·21 "	·034 ft.
40 "	·26 "	·125 "
56 "	·29 "	·18 "

Under such circumstances, even the tallest man, standing bolt upright, is only very little exposed. A shorter man stooping slightly is perfectly safe.

With the same range and gun, using time fuzes, the angle of descent is 6°. By bursting the shell rather high, a larger angle of descent is obtained for the lowest effective bullets. With this view, suppose one-fourth the diameter of the cone of dispersion is made to strike the parapet; the following will then be the heights above plane at which the shell opens:—

	ft.
10 yds. short	5·0
20 " "	7·2
30 " "	9·5
40 " "	11·7
50 " "	14·0

and at the same gun pit the portions of the detachment exposed to fire would be—

Burst.	Nos. 2 and 3. ft.	Nos. 4, 5, and 1. ft.
10 yds.	·93	1·83
20 "	·67	1·34
30 "	·59	1·19
40 "	·55	1·09
50 "	·52	1·04

These amounts are supposing the parapet does not suffer, and that the bullets which strike even close to the crest have no effect. In practice, however, the parapet is found to suffer, and many bullets, when they have the descending angle due to time shell, pass through it, having remaining velocity sufficient to make them effective.

It may fairly be assumed, therefore, that time are more effective than percussion shrapnel at such an object; and the correctness of this view is fully confirmed by the practice at Okehampton (*vide* Report, p. 82), in which the effects of the two were compared.

Before the percussion shrapnel were fired, the parapet had already had two direct hits and 22 rounds of common and water shells. Twelve rounds of percussion were fired, with the following result:— 50, 65, 55, 65, 85, 15, 25, 8, and 2 yds. under; 2 direct hits, and one shell 45 yds. over. This, considering the size of the object, may be taken as fair practice.

Result.—Face of work much damaged. 1 dummy disabled (No. 2), hit in 3 places.

The work was then thoroughly repaired, and 12 time shrapnel fired. The following was the range report. The whole burst short with one exception:—

6 above plane ... 100, 8, 200, 100, 90, 40 yds.
4 on plane ..... 20, 160, 40, 6 yds.
1 blind ..... 50 yds.
1 on plane ..... 10 yds. over.

Only six effective shell out of twelve cannot be called good practice the increased damage is, however, very marked.

Result.—The whole detachment (6) *hors de combat.* Gun pit full of shell fragments. Wheels much damaged. Many bullet grazes on guns and carriages.

The time fuzes were fired in 5 minutes, the percussion in 7 minutes.

In addition to the actual losses in the pits themselves, it must be remembered that the ground in rear is, when time fuzes are used, covered for some hundred yards or more with effective fire. The bringing up of ammunition and replacing losses in the detachment would from this cause be a service of considerable risk. With percussion shell, however, since even the lowest bullets start with elevation, this advantage is entirely lost.

When percussion shrapnel are used banks, the sides of ditches, and any slight inequalities of ground afford considerable protection to infantry and artillery. The searching fire of time shrapnel would suffer little loss from such obstacles.

In support of this view, the practice at Okehampton (*vide* Report, p. 85) may be cited. The target was half a battalion in open attacking order, the firing lines kneeling and taking every advantage of cover which the broken and rocky nature of the ground afforded to an exceptional extent. The supporting lines were lying down. There were 103 dummies in the 1st line, 50 yds. interval between each line: the numbers in the 2nd and 3rd are not given.

Percussion and time fuzes, 36 rounds of each.	Result.		
	1st line.	2nd line.	3rd line.
Percussion	35	1	1
Time	44	5	1

It is unfortunate that in the practice at shelter trenches (p. 83 of the same Report) the different effects produced by time and percussion fuzes are not distinguished.

A small rise in front of an object is very prejudicial to the effect of percussion shell, since it absorbs much of the cone when the burst is close up; and when the shell strikes on it, it adds considerably to the angle of ascent and retardation from graze. Such a contour of ground, however, does not materially lessen the effect of time shrapnel, even if it does so at all.

In the practice described at p. 81, Okehampton Report, the range was 1500 yds.; the target was a 16-pr. gun detachment of 8 dummies, with two 6-ft. × 6-ft. targets in rear, to represent the limbers with drivers dismounted. The gun was placed about 50 yds. in rear of a mound having a slope of 1 in 16 each way, with its muzzle just clear when laid point blank; the two targets were about 35 and 50 yds. respectively in rear. The ground was firm dry peat, with shale below

it—good ground, in fact, for percussion fuzes. The results of 8 rounds of each nature were as follows :—

Shell.	Disabled.	Hits.			
	Detachment.	Gun.	Wheels.	1st target.	2nd target.
Percussion	2	Nil.	Nil.	1	1*
Time	8†	1	22	17	18

* Direct hit of shell. † Whole detachment.

Time of firing rounds. { Percussion ..... mins. 3 / Time 2

Part of the diminished effect produced by the percussion shell may be due to another cause, which has already been pointed out (p. 192). It has been shown that to obtain good effect the shell must at ordinary ranges be burst close up. By the time the cone arrives at the target, therefore, it has only a small diameter and this necessitates very careful shooting—a matter of difficulty when either the ground is rough, the wind strong, or the object moving. In addition, every irregularity of ground which tends to deflect the point of the shell must have a disturbing tendency.

In the case just quoted, for instance, the best distance of burst would have been about 18 yds. short. This gives a spread of only 7·5 ft.; the entire effect of a shrapnel 8·5 ft. to the right or left of the muzzle of the gun would have been lost.

In this last experiment and that described at p. 197, the difference in effect on the rear of the object is very marked; and this leads to the consideration of the different results produced with time and percussion shrapnel respectively when the object attacked has depth. Percussion, since they must burst on plane with an ascending angle, cannot possibly do more than produce a comparatively small effect immediately in front; they cannot distribute their fire over the whole target from front to rear as time shell do. They may, at times, seem to do so, when such a target is used as in Series Q. and R., Okehampton Report (9-ft. × 9-ft. × 2-in. targets, representing a regiment of cavalry in quarter-distance column, the squadrons having 36 paces of front, 5 paces between ranks, and 11 paces between squadrons). Here, by bursting through targets in different positions in the column, the effect seems spread over the whole; but this is due to a number of shells acting partially, not by each shell, if it is well aimed, distributing its effect over the whole object.

Compare, for instance, the 9-pr. at this target (Okehampton Report, p. 74). 4 time shells are given as "good" out of 6 fired. Range, 3540 yds. All the squadrons suffer, with a result of 60 dummies disabled; the effect being fairly distributed.

At p. 75, on the other hand, with 12 percussion shells from the same

gun, No. 1 Squadron has 6 strikes only. Then, through the front rank of No. 2 are 2 direct hits; and consequently the return of the rear rank is, through 65, lodged 54, struck 10. In this rank, again, is 1 direct hit, and consequently the front rank of No. 3 suffers slightly; its rear rank and the rest of the target are untouched. The result is 20 dummies disabled.

Again, in Okehampton Report, at p. 79, with 16-pr. percussion shrapnel, the front rank of No. 1 Squadron has through 3, lodged 2, struck 116; its rear rank is untouched; both ranks of No. 2 and the front rank of No. 3 are untouched, except by 4 strikes. One direct hit in the latter, however, leaves its mark on the rear rank, which has 22 hits. On this rear rank, again, there is a direct hit, giving a slight effect on the front rank of No. 4. There are 2 direct hits on this front rank, the result being two clusters of bullets in the rear rank.

During the whole of the series referred to the time fuzes were entirely experimental, and the practice so inferior in consequence that any comparison made between them and percussion must be very advantageous to the latter. In the practice recorded at pp. 70–71, Okehampton Report, the two natures were pitted against each other, and service time fuzes were used. It is here given *in extenso*:—

Series Q.—Experiments 62, 23.—16-pr.

30th August and 1st September, 1875.

Table of Mean Results.

To ascertain the comparative effect of shrapnel shells with both percussion and time fuzes, when fired at a target representing a regiment of cavalry in quarter distance column of squadrons.

8 rows of targets, each target $9' \times 9' \times 2''$; 12 targets per row.

5 paces between ranks, 11 paces between squadrons, frontage 36 paces, depth 53 paces.

Range, 2000 yds. Guns on same level as target.

Particulars of ammunition.	Number of rounds.	Total hits.			Grand total hits.	Total troopers disabled.
		Through.	Lodged.	Struck.		
Shrapnel percussion	36	222	194	1158	1574	131
Shrapnel time	36	397	131	984	1512	182

The following are the experiments in detail:—

Series Q.—Experiment No. 62.—16-pr.

Practice 1st September, 1875, at a column of targets (No. 4) representing a regiment of cavalry in quarter distance column of squadrons. Range, 2000 yds. to head of column.

36 shrapnel shells with time fuzes fired independently in 10 minutes, of which

2 burst 50 yds. over, 4 fell into column but were blind, 7 burst in air about 100 yds. short, 2 grazed about 30 yds. short and were blind, 4 burst in air about 30 yds. short, 1 burst on plane 120 yds. short, 4 burst on plane about 25 yds. short, and 12 burst either over the column or in it.

Grand total hits 1512
Troopers disabled..... 182

Particulars.		No. 1 Squadron.		No. 2 Squadron.		No. 3 Squadron.		No. 4 Squadron.	
		Front rank.	Rear rank.	Front rank.	Rear rank.	Front rank.	Rear rank.	Front rank.	Rear rank.
Bullets or splinters.	Through	81	33	18	17	36	15	99	69
	Lodged	10	15	24	8	4	36	19	15
	Struck	121	103	145	47	272	191	46	59
Direct hits of shell....		3	2	7	6	5	4	—	—
Total hits		215	153	194	78	317	246	166	143
Disabled		30	24	21	15	25	21	20	26

Series Q.—Experiment No. 61.—16-pr.

Practice 30th August 1875, at a column of targets (No. 4), representing a regiment of cavalry in quarter distance column of squadrons. Range, 2000 yds. to head of column.

36 percussion shrapnel shells fired independently in 5 minutes, all of which fell either into the column or a little short of it.

Grand total hits 1574
Troopers disabled..... 131

Particulars.		No. 1 Squadron.		No. 2 Squadron.		No. 3 Squadron.		No. 4 Squadron.	
		Front rank.	Rear rank.	Front rank.	Rear rank.	Front rank.	Rear rank.	Front rank.	Rear rank.
Bullets or splinters.	Through	16	60	47	44	28	9	—	—
	Lodged	11	16	69	42	28	21	4	3
	Struck	66	292	376	185	140	88	10	1
Direct hits of shell ...		5	7	—	3	1	1	1	—
Total hits		98	375	492	274	197	119	15	4
Disabled		17	20	25	24	15	19	8	3

Comparing these, the evenness of distribution of time fuzes over the whole of the column is very marked; with the percussion, the rear seems to have come off almost scathless. The return of dummies (182 to 131) shows the superiority of the time shell in the most marked manner. If, deducting blinds and overs, we take only the 28 effective time shell which remain, the result is still more striking; the dummies disabled per shell being

Time, 6·5; percussion, 3·6.

The same remark as to the far greater power of time shrapnel compared with percussion, may be made here as at p. 187. The throughs are 397 and 222 respectively; or the time gave an average of 14·2 per effective shell, and the percussion of 6·2.

It may be thought that the retardation, and consequent loss of power after graze, has been overstated. At p. 79, Okehampton Report, is some practice with percussion shrapnel which shows it very clearly. In the front rank of No. 1 Squadron are some hits which must have been made by shell after graze, as there is nothing for them to burst through; and they must have burst near up, for the return of disabled is only 3 dummies, and the hits must therefore have been close together. Three shell have burst without grazing—viz., one through the front rank of No. 3, and two through the front rank of No. 4 Squadron. Their effects are on the respective rear ranks. If we contrast the two groups, we have—

Shell.	Through.	Lodged.	Struck.	
After graze.....	3	2	116	No. 1 Squadron.
Before graze	39	1	13	Nos. 3 & 4 Squadrons.

When the ground on which the object stands slopes rapidly towards the battery, the loss of effect with time fuzes is very small; and any men exposed in such a position would find greatly increased difficulty in obtaining shelter from a fire necessarily so searching. With percussion fuzes however the case is very different; if the slope is considerable, unless the ground is exceedingly favourable for them, they will either bury themselves, or else, rising at a very high angle with a greatly decreased velocity, the result will be out of all proportion small compared with the amount of ammunition expended.

With ground moderately broken and soft, the loss is quite extraordinary, as is shown from the practice at p. 61, Okehampton Report, of which the following table gives the result:—

Series.	Gun.	Range.	No. of shell.	Burst short.	Through.	Struck.	Lodged.
		yds.		yds.			
1	16-pr.	1300	5	from 11 to 15	12	1	6
2	9 "	"	3	" 1 to 10	24	13	10
3	16 "	"	7	" 1 to 20	7	3	6
4	9 "	"	5	" 1 to 20	14	20	9
5	16 "	1400	5*	" 3 to 80	68	34	5
6	9 "	"	2	" 15 to 20	2	—	—
7	16 "	"	6*	" 4 to 20	64	47	13
8	9 "	"	1	" 0 to 20	"	—	"

* Two shell, 400 and 100 yds. short, eliminated.

In Series 5 and 7 the effect seems due to one shell which has burst very short. In the 5th, two adjacent targets (a front of only 7 men) have received 102 out of the total 107 hits. In the 7th, the same extent of front, 76 out of 124 hits. There is no effective spread.

When objects instead of being standing, as has been the case with the targets in the practice hitherto considered, are in motion, percussion are at a great disadvantage as compared with time shrapnel. In the first place, the very good shooting necessary for their full effect is difficult of attainment. In the second, even while the shell is in the air, the object must have moved; unless, therefore, an allowance be made—and this is no easy task—the best shooting may be thrown out. Take as an instance a body of infantry advancing by rushes, opposed by the fire of a 16-pr. at 1725 yds. range, the time of flight of its shell being then 5 secs. They pass over the ground at the rate of 6 miles an hour, or 3 yds. per second, and have therefore moved 15 yds. while the shell is in the air. At such a range an error of $\pm$ 15 yds. would have a serious effect on percussion shell; it would not, however, materially affect one fired with a time fuze.

The loss of effect due to increased range, which has already been shown to be the case with time shrapnel, is very great when percussion fuzes are used. There are unfortunately only two ranges the practice at which can be distinctly compared, since in that at pp. 61–64, Okehampton Report, the ground has already been shown to have been so unfavourable for percussion shrapnel that the results are unreliable. They are the 2000 yds. practice at p. 71, and 3930 yds. at p. 77, Okehampton Report; the effect on the front ranks can only be considered, in order to eliminate any shells that burst through targets close in front of others.

Range. yds.	Through.	Lodged.	Struck.	Dummies disabled.
2000	16	11	66	17
3930	3	2	116	3

The large proportion of strikes at the last range, and the small number of men disabled in comparison with the number of hits, shows how great the falling off has been in power and spread.

Up to this point, some practice at Okehampton in which percussion gained an advantage over time shrapnel has not been mentioned, except when the action of the latter was being considered. The only inference then drawn was that time, after all, had far greater power than percussion.

When comparing the two natures, the advantage thus gained must be admitted; some remarks may, however, be offered which will show that there may be reasons for supposing that the results are not altogether reliable.

The practice is as follows:—

9-pr. R.M.L.

Experiments carried out, 27. 8. 75, to ascertain the relative effects of shrapnel shells, burst by time and percussion fuzes; the fire being directed at an object consisting of two rows of 6-ft. targets, 9 targets in each row, with an interval of

11 yds. between the rows, to represent a body of troops moving over a hill (Target No. 8). Each half-battery had its own target as above, a distance of 150 yds. separating the two targets, which were placed on the brow of a hill, with hardly any rising ground behind them. The half batteries, with an interval of about 50 yds., manœuvred at a canter and came into action at unknown ranges.

One half-battery used percussion fuzes, the other half-battery used time fuzes.

The latter were allowed two percussion shells at each position, to assist them in picking up the range. Four positions at different distances were successively taken up—viz., at about 2300, 2200, 1600, and 1200 yds.—and each half-battery fired as rapidly as possible for about 7 minutes from the word "Action."

	Time.	Percussion.
Grand total hits	497	 796

Particulars.		Time fuzes, 74 rounds.		Percussion fuzes, 101 rounds.	
		1st row.	2nd row.	1st row.	2nd row.
Bullets or splinters.	Through	137	157	46	96
	Lodged	55	73	149	412
	Struck	41	34	44	49
Total hits		233	264	239	557

With the time shell the shooting was indifferent throughout; at the last range indeed bad.

With the percussion fuze it will be noticed that the 2nd row has suffered considerably more than the 1st. It is quite impossible that this could have been caused by shells which burst nearly on the ground in front of the latter. Such a result can only be explained by the fact, which may be seen from the return of the points of bursting of the shell given in the Report, that 20 shell burst through the 1st row and consequently closely imitated the action of time shell on the second.

To this it may be replied that the same would happen in actual warfare from shell bursting through the front rank. It would no doubt to a certain, but not to the same extent; because a rank of infantry or cavalry would not present the same area as wooden targets, and a certain number therefore of the shell would pass through, and even if they burst on the rear rank would be much less deadly. Again, a shell bursting in or through a man or horse, would have a considerably greater amount of effect abstracted than if it had only passed through 2 ins. of deal.

The number of men disabled is not given—and this, after all, is the great criterion of good shooting.

When contrasting time and percussion shrapnel, it is impossible not to draw comparisons between the relative excellencies of the fuzes used with them.

The percussion are certainly very perfect. They can be carried in the shell; their preparation is exceedingly simple (even if the safety pin is not withdrawn, they will with the 16-pr. very generally act); their action

leaves nothing to be desired, and the per-centage of failures is extremely small. Can it be said that the time fuze is in its way as perfect?

Time fuzes (1) cannot be carried fixed. (2) They can seldom be prepared at the limber, because when in presence of the enemy it is often—indeed generally—at a considerable distance from the gun; while, therefore, No. 6 is going and returning and the process of boring is being carried out, there is considerable loss of time, during which the length of the range may have altered. (3) If they are so prepared, No. 1 cannot see whether they are well or badly bored, since it must be done by No. 7 at some distance from him; and this leads to the direction that in almost any instance he should do it himself. He has already more than enough to do, if he superintends the work of the detachment; is constantly looking out for directions from the C.O.; lays with care; and watches the effect of his fire: besides which, the manipulation of live shells under fire cannot be absolutely safe. (4) Even with the hook borer, there is a chance of bad boring, with the hand a still greater one; with this latter there is also the possibility of No. 1 trying to cut half-tenths—an attempt very generally fatal to good practice. (5) The confusion which arises in the minds of both N.C.O.'s and men from the combination of secs. of flight and $\frac{1}{10}^{\text{ths}}$ of inches is often very great; especially when fire is required to be rapid and there are many other points to attend to; the mere teaching is difficult from this cause. (6) In the M.L. fuzes the lighting of the composition by quick-match is not altogether satisfactory. It is from deterioration of the match that old fuzes are always found to burn longer than new, quite as much as from an alteration in the condition of the fuze composition itself; and undoubtedly in very wet or even damp weather, though the match is uncovered for only a short time, there is a considerable loss of quickness of lighting, and even chance of failure. (7) Graze has a very great effect on them. (8) The following table shows what can be effected with them, taking the 16-pr. as the gun used.

5-secs. fuzes.			9-secs. fuzes, beginning at 1 in.		
Tenths of fuze.	Range.	Difference due to 1 tenth.	Tenths.	Range.	Difference.
	yds.			yds.	
1·0	200	—	10	1725	—
1·5	295	95	11	1875	150
2·0	390	95	12	2020	145
2·5	485	90	13	2165	145
3·0	575	90	14	2305	140
3·5	665	90	15	2445	140
4·0	755	90	16	2580	135
4·5	840	85	17	2715	135
5·0	925	85	18	2845	135
5·5	1010	85	19	2975	130
6·0	1095	85	20	3100	125
6·5	1175	80			
7·0	1255	80			
7·5	1335	80			
8·0	1415	80			
8·5	1495	80			
9·0	1575	80			
9·5	1650	75			
10·0	1725	75			

Up to 1725 yds. range, the distances between the points where the shell can be burst leave little to be desired; but as soon as this limit is passed and the 5-secs. fuze can no longer be used, the differences are doubled. In other words, as the range increases and it becomes more than ever necessary to burst within narrower limits, the possibility of doing so is taken away.

Suppose, for instance, an object is 1860 yds. distant; the choice is given of bursting at 1875, when the whole effect is absolutely lost, or at 1725 yds.—135 yds. short, which would certainly entail a considerable loss compared with 80 yds. which has been shown to be the best distance.

Having thus attempted to examine closely the action of shrapnel, we may proceed to consider its application to the various requirements of actual service. First as to objects, and then ranges.

The objects are men and horses which can be struck by a direct fire or effective ricochet. As the conditions under which cavalry, artillery, and infantry expose themselves in such a manner differ, and the three arms present in themselves such different targets, it may be as well to consider them separately.

1. Cavalry and artillery when mounted present a considerable height to the effects of fire. In such a case the ascending angle of percussion shrapnel, though still diminishing its power, does not do so to so great an extent as with dismounted men; and with them, therefore, a freer use of percussion shrapnel may be allowed.

Cavalry may expose themselves in large masses without movement—only, however, as a rule, at long ranges; and, as will be shown further on, percussion shrapnel will then generally be used.

At ordinary or short ranges, cavalry when in masses will almost always be in rapid movement; and this again may make the use of percussion fuzes desirable.

In both these cases however time shrapnel will, shell for shell, give a far greater result; and if the skill of the battery and time will admit, it should be used.

Cavalry may attempt the capture of a battery by a sudden flank attack. Shrapnel with percussion fuzes ought to be used if they discover themselves soon enough; for time is thus saved, and, the range being short and the ground necessarily good, they will be very effective; but case must take their place at the very first possible moment.

Small bodies of cavalry or a General's Staff will at times afford an object which it may be desirable to attack. Percussion shrapnel may perhaps afford the best means of taking them by surprise; but the practice must be very good to ensure fair results as the range will very generally be considerable.

2. When artillery is the object of attack the aim may be either to keep down their fire or destroy their mobility. The former is most easily effected by causing large losses amongst the men; the latter, among the horses. It need hardly be insisted upon that the old idea of crippling a battery by injury to *matériel* caused by common shell is

impracticable. The experience of the Franco-German war shows how insignificant such injury is even under the heaviest fire; and the Okehampton experiments tend, as far as they go, to confirm it. It is to shrapnel then that we must look to effect our purpose.

When the battery attacked is in action, and the aim is to keep down its fire, shrapnel with time fuzes are undoubtedly the most effective. If the line of fire is at right angles to its front, not only are the gun detachments likely to suffer, but the whole of the ground in rear is covered with an effective fire, the result being that the supply of ammunition to the guns becomes a service of danger; besides which, should such a formation as that laid down for a battery in action by our "Field Exercise" be adopted, the limbers would, unless they could be retired a considerable distance or find effective cover, be exposed to most of the bullets ranging beyond the guns. It will, of course, always be advantageous if, by moving towards a flank, the attacking battery can get more than one of the enemy's gun detachments into the ground covered by the cone of dispersion; but it is often, or indeed generally, difficult to manage this, and much or all of the effect on the limbers just pointed out would then be lost.

When the aim is to destroy the mobility of the battery, every effort should be made to reach the limbers with time shrapnel. The difficulty of gaining any advantage from the use of percussion is patent from the results of the Okehampton experiments.

The position of all others in which a battery may have of necessity to expose both men and horses to a very great extent, though only for a short time, is when it is coming into action. Such an opportunity should never be thrown away by the opponents. An officer with a battery on the defensive, has an especial advantage in this respect when the ground is at all open; he can foresee with something like certainty the positions which the enemy are most likely to occupy, and his range-finders should have every such range carefully found beforehand. A few shells should be kept ready for them, and the quickest fire possible delivered at the critical moment. For such a purpose time shrapnel will give the best results, but if time does not admit of the preparation in advance just recommended, percussion should be used rather than throw away the opportunity.

Artillery will naturally take advantage of every possible species of cover, and this will necessitate the use of time rather than percussion shrapnel. The Okehampton experiments at a gun on the reverse slope of a small knoll and in a gun pit show this fact so plainly that it need hardly be insisted upon.

When a battery is on the reverse slope of a hill, it may often seem unnecessary to retire the limbers very far from the guns, since the height of the ground will generally appear to give perfectly ample shelter. Time shrapnel is, however, most effective under such circumstances; its angle of descent—especially that of the lower portion of the cone—is quite sufficient to sweep the face of most hills that a gun or limber could stand on, especially at the longer ranges. Even percussion shell would be very effective, since they would have a comparatively very low angle of ascent after graze; when they have been used, there

are instances on record where the facing slope has been found to be the safer position. The remarks at p. 201 tend to confirm this view.

3. In the case of infantry, even when standing in the open, their want of height tends to make the use of percussion shrapnel very unadvisable; and this is more and more the case when they take advantage of cover or lie down. The different conditions may be divided mainly into three—(1) when they are in column formation, or smaller columns in support; and (2) when in the extended order adopted when the enemy's fire becomes heavy. Their rate of movement will in the 1st case be comparatively slow; in the 2nd quicker, but still not very fast; in the 3rd it will be at a sharp double, as rushes are made from one position to another. In all three there will be considerable pauses; during which, however, advantage will be taken of cover, or the men will at least lie down.

The shelter will, in the case of the attacking line, be natural obstacles —such as the reverse slopes of hills, banks, ditches, hedges, woods, &c.; but in all cases where the defenders have well chosen positions, they must to a very great extent expose themselves in the open. On the part of the defence, field works (often on a large scale), shelter trenches, gun pits, and buildings rendered defensible will be largely made use of.

1. The power of common shell against columns has been proved to be very slight. It is to shrapnel that we must look again for good results.

Under certain circumstances percussion shrapnel may have to be used. The best place to burst them seems to be on the front rank or in the column itself. At very short ranges they might be burst close to the front rank; but at such ranges it is very unlikely that columns would expose themselves, and it is only in the case of a surprise that such would be the case.

Time shrapnel, with their power of covering the whole column from front to rear, will undoubtedly offer the best chance of success; and they should consequently always be used when possible. They should be directed on the centre of the column, and burst at the distances in front of it already laid down for the different ranges. The recommendation often given is to lay at the head of the column; but this necessitates wasting a large portion of the cone of dispersion on the ground in front, and the rear companies may hardly be reached with an effective and well spread fire.

2. As will have been seen from the Okehampton experiments, an attacking line in extended order is exposed to very severe treatment by a battery immediately in their front; and this is due very much to the great amount of ground which time shrapnel can cover with effective bullets in the direction of the line of fire. Percussion shrapnel were unfortunately not tried under the same conditions, but it is hardly probable that they would do anything like the same work.

A glance at the plans of the ground covered by shrapnel, which accompany this paper, will show that the projectile would be most

effective at such an object when the major axis of the figure corresponds with the line to be attacked, and that the nearer they approached a right angle to one another the more effect would be lost. It would appear, therefore, that if batteries could turn their attention to lines either to their right or left rather than to those in their immediate front, and this even at the risk of having to act at longer ranges, they would increase their effect; the drawback to such a recommendation being, of course, the difficulty under such circumstances of obtaining a fire evenly divided along the line of attack from a number of batteries in the line of defence.

When a particular point of a line of defence is threatened with a serious attack, it will often be advisable, if the ground and other conditions render it possible, to trust to batteries on the flank rather than in the position itself. They will not in the earlier portion draw a fire which must seriously incommode the other troops in the position; and as the attack advances the greater will become the effect of their fire.

The batteries actually in the position attacked will do best to turn their attention as soon as possible to the supports, especially while these latter retain the company column formation, leaving the infantry to keep down and draw off the fire of the enemy's first line. In the first place, the supports offer a much better object; and in the second, a great point is gained if they can be checked or seriously weakened. Supports will nearly always push on however great may be the losses in the front; but they are not so ready to do so when they are themselves shaken by an effective fire. Those in front will generally press on against very heavy fire if they feel they are strongly and actively supported; but as a rule they soon lose heart when the contrary is the case, and at the best do little more than maintain their ground in the hope of assistance arriving. Even should they still press on, the attack must be delivered with a weak line unsupported; and this, since it must certainly fail, is really a gain to the defence.

When infantry avail themselves of such cover as described above, or lie down, shrapnel shell with time fuzes has, from the searching effect of its angle of descent, an infinitely greater chance than percussion. It must be remembered that when the cover affords considerable protection, it is necessary, as already described in the matter of gun pits, to burst the shell rather high, so as to obtain the greatest possible angle of descent for the bullets without throwing away too much of the effective portion of the cone. In the case of shelter trenches, the remarks on lines given above will also apply.

Against infantry holding such a position as the outskirts of a wood it would seem best to use shrapnel with time fuzes as long as it may be inferred, from the amount of fire or other causes, that they are in force on its outskirts, and when therefore the only cover they could have is a small depth of brushwood. As soon as there is reason to believe that they have retired further into the wood, and have such cover as trunks of trees and a large depth of brushwood, shrapnel would be no longer effective and common shell should take its place.

The above remarks have reference more especially to the action of the artillery of the defence. They will, however, apply equally to the attack. The latter, however, will always do well to have some rounds

of percussion shrapnel ready for emergencies or surprises, to which they are far more liable than the defence. They must, however, remember that two considerations render its use, as a rule, unadvisable. In the first place, the attack must nearly always be made from low against high-lying positions, and the effect of rising ground in destroying the power of percussion shrapnel has already been shown; when percussion shrapnel is used against troops on the actual crest of a hill higher in level than the position from which it is fired, the chance of obtaining good results on the line itself is very small, and the shells can cover no ground in rear. In the second place, the defence have always more chance of shelter, against which percussion shrapnel is powerless.

When speaking of cover it must, of course, be acceded at once that when it is very complete and strong compared with the power of the bullets—as in the case of houses, loopholed walls, pallisades, &c. —shrapnel fire is out of the question.

An exceptional use of shrapnel is to attempt, by removing the plug and loading it point foremost, to attain the effect of case. The result, even at 100 yds., is comparatively very small, and decreases quickly with the range; so much so, that only the direst necessity should tempt an officer to waste so valuable a projectile in such a manner.

Another exceptional use is in destroying abbatis or pallisades, when, after shattering them with common shell, it is desired still further to break them up. In this case, of course, it is desired to get the bullets close together, and percussion fuzes will give the best results.

Ranges may be roughly divided as follows:—

		yds.
1.	Distant.....	above 3500
2.	Long	from 2500 to 3500
3.	Ordinary	„ 1200 to 2500
4.	Short	„ 800 to 1200
5.	Close	under 800

1. When speaking of length of range, it must be remembered that it is limited not so much by the distance to which a gun may be able to project a shell as, in the first place, by that at which the shell still retains sufficient power to be formidable; and in the second, that at which the eye is still able to appreciate the accuracy of the practice and the results obtained.

This possibility of correct observation is such an absolute necessity for obtaining an effective fire, and its limit is reached, as a rule, so much before that of the mere power of the gun, that, though the latter may be fairly taken as the ultimate, the former must always be the practical limit.

Accuracy is the first essential of fire, especially as the range increases and the ground covered by the shell decreases; and although we can by the use of range-finders eliminate the most fertile source of error, there are still so many others remaining that range tables can after all only approximate to the truth, and it is by observation alone that they can be corrected. Range tables are constructed from data obtained

in practice under the most favourable possible conditions—such as the best and most even brand of powder, new fuzes, &c. Under the ordinary exigencies of service hardly one of these conditions can be expected to remain constant, and the consequent variations must be estimated and allowed for.

The range at which effect can be judged with certainty is limited by a variety of circumstances. The most important are—(1), the actual distance; (2), atmospheric conditions—such as fog, smoke, twilight, &c.; (3), direction of light; (4), the ground on which the object stands; (5), the amount of smoke due to the burst of the shell; (6), the number of batteries simultaneously in action which tend to confuse the observations.

The third is that which perhaps strikes one the least, and yet its effect is very marked in practice. For instance, at Okehampton, on the 16th August, when the objects were white dummies placed on the face of a hill covered with dark heather, and the ranges varied from 1625 yds. to 3150 yds., we find the remark made that "a bright sun threw a strong light towards the battery, and rendered the dummies almost invisible." Indeed, though the day was in other respects quite fine, it was impossible at times to see them through the sights even at the shorter ranges, and the practice was in consequence much delayed.

The art of forming a correct estimate of shrapnel fire is most difficult at even short distances on ordinary ground, especially in the case of time fuzes being used. It can only be attained by constant practice and a thorough knowledge of the action of the projectile. It is easier with percussion shrapnel, but at long ranges the smoke of their bursting charge affords so small a mark that common shell may often have to be used in preference; unfortunately, the difference in weight between the two projectiles causes a sensible difference in their respective ranges, and consequently after an estimated range has been verified by the latter, an allowance has still to be made from this cause when the former take up the fire.

Distant ranges may be necessary under the following circumstances, amongst others :—

a. When making a reconnaissance, it is desired, without too great exposure on one's own part, to induce the enemy to disclose his strength or position.

b. Against such an attempt, when such disclosure is of no great importance.

c. When, acting with a retaining force, a portion of the artillery attempt to induce the enemy to halt and show front, while the remainder press on to closer quarters.

d. From defensive positions, when the enemy, fancying that he is in safety, may expose himself in large masses.

e. When fire has to be concentrated from an extended line of batteries on an important position.

f. In the pursuit when, an opportunity offering itself of throwing the enemy into confusion during the passage of a bridge, defile, or some such obstacle, either time is of the first importance, or the ground in front is so held that the batteries cannot get nearer.

g. In a retreat, when the range is constantly lessening, and it is of importance to keep the batteries as long in action and as much out of the road as possible.

When the position of the enemy is such that he can by simply shifting his ground quickly avoid the fire—as for instance, a regiment of cavalry in case *d*—it will be necessary to make the fire as much a surprise as possible. With this view, the range having been carefully ascertained, and every allowance which pre-experience of powder, fuzes, &c., may suggest having been carefully made, a salvo should be fired and be followed immediately by shells previously prepared and ready at the guns themselves, in order to save time.

When however this is not the case the range should, after having been carefully ascertained, be verified by one or two common shell, and, the necessary allowance being made, shrapnel should then follow as soon as possible.

Percussion fuzes must be used, as the present time fuzes are too short to be available. This is to be regretted, since in the Okehampton experiments when the experimental time fuzes used were successful, their effect was so much greater than those of percussion as to give every reason to believe that they would prove as far superior in actual practice as the theory of their action would lead one to suppose.

The great loss of power, and consequently of effect, which shrapnel suffer from increase of range is so great that the responsibility of the officer who uses them at distant objects must be considerable. In any of the cases above stated opening fire early may be absolutely necessary; the only responsibility remaining will then be that it is not continued one moment too long. If however there is no such absolute necessity, surely some very sufficient reasons should be demanded from an officer who in the earlier and comparatively unimportant period of an engagement, when the effect produced could from the length of the range at best be but small, should expend ammunition which later on would be capable of exerting the enormous power that shrapnel at ordinary and short ranges has been shown to possess; and which might, if reserved for really critical periods, exercise a deciding influence on the fortunes of the day.

2. To long ranges the foregoing remarks will apply to a modified extent. The possibility of verifying the range with shrapnel is greater, the loss of power in the projectile is less, and there is therefore less chance of wasting ammunition. Time fuzes are available up to a certain point; they should therefore be used when other conditions are favourable.

It need hardly be insisted upon that firing at moving objects at distant and long ranges is a matter of great difficulty. If such a course should seem really necessary—as for instance in the last of the cases contemplated above—the range of some well defined spot which the enemy must pass should be ascertained, and if possible verified by a few rounds. Fire can then be opened when they are at a distance from it sufficient to compensate for the allowance due to the time of flight of the shell.

3. At the longer ordinary ranges, unless time is of paramount importance, it will always be as well, even when the distance has been accurately obtained by the finders, to verify it by one or two percussion shell fired with deliberation, unless from previous experience the allowances made necessary by the state of the ammunition, &c., are well known. Such a precaution is less necessary at the shorter ranges, still, if the object is one which demands great accuracy of fire—such, for instance, as a gun pit—it will generally be worth while adopting; and in every case when time is not of importance no harm can, and much good may, result from its employment.

When recourse has been had to percussion for such a purpose, and the fire has to be continued with time shrapnel, it must always be borne in mind that the former is burst in front, and passes consequently below the centre of the object; whereas the latter should, to attain the best results, be directed slightly above the centre. The elevation should therefore be at once increased, either by the rough and ready method of aiming higher on the target, or by the more accurate one of giving a few minutes more on the tangent scale.

Time shrapnel should as a rule have the preference for ordinary ranges, except when, an extremely rapid fire being necessary and the form and nature of the ground being favourable, the use of percussion is preferable. It might at times be advisable to retain percussion shell when, from heavy losses, a battery might be deficient in the number of skilled men necessary for the slight extra labour and knowledge required for the use of time fuzes.

Moving objects which present themselves at these ranges may, and indeed in many cases must, be fired at. The method already suggested in the case of distant and long ranges may often be used with advantage; if however, either from a want of definite points to lay on, or the waste of time and ammunition which might result from doing so, such a course is undesirable, the guns must be laid just in front of the object. Since the rate of all paces is well known, as soon as one range has been hit off, the others ought to be easily obtained by a simple observation of the time between the rounds. The arguments for and against time and percussion fuzes for such a purpose have already been entered into at length. The conclusion arrived at was that, from the amount of ground they cover, the former would under ordinary circumstances give by far the better results.

4. At short ranges, since time is almost certain to be an important factor in the question, the preference might be given to percussion fuzes, especially because the shorter the range the smaller is the waste of power due to their use and because the nature of the ground becomes also of less importance; under such circumstances it is unfortunate that they were not tried in comparison with time fuzes in the attack by infantry from 1000 yds. during the Okehampton experiments. It certainly seems very unlikely that a better result could have been obtained from their employment than was the case with the time shell which was used; nevertheless, in artillery questions, any theory which is not put to the crucial test of practice is so dangerous and may lead to so many errors, that it is always safer to try

everything of which there can be any question. The writer cannot however but record it as his opinion that, even were the factors of time and effect alone taken into consideration, leaving out altogether the very important one of the amount of ammunition expended, the preponderance of advantage would still be on the side of the time fuzes.

5. At short ranges, time being more than ever valuable, and the disadvantages of the ascending angle reduced to a minimum, percussion shell might with advantage be used entirely until the limits of case were reached, when of course the latter would have the preference.

A few suggestions regarding Instruction and Practice may be offered, in conclusion, as not altogether out of place in a paper like the present.

Instruction may be divided into three main points:—1, of what a shrapnel is capable; 2, how it acts; and 3, how the effects produced may be judged at the distances which actual service necessitates.

1. In teaching the first, such reports of practice as those referred to in this paper are invaluable; it is therefore much to be regretted that more of them do not exist. Conclusions drawn from such practice, coming from an authoritative source and thus carrying sufficient weight, would also be most valuable. The necessity of all concerned knowing perfectly the full power of the projectile need not further be insisted upon; without such knowledge, results may be accepted as satisfactory, and even excellent, which are far below what might be easily obtained.

2. In learning how a shell acts study of its theoretical principles is of importance as a prelude to actual observation of its effects; indeed either is of little use without the other. Mere theory is always to be mistrusted; without it, however, many facts which might be gained in observation may be lost, and in addition there is even a chance of false conclusions being drawn.

3. After such a preparation in theory, the effects should be observed first on the Range and then from the Battery. The reason of this—which it must be allowed is rather reversing the order which at present obtains—is that the pupil, until he can by close observation master thoroughly the manner in which a shell really acts, is little likely to judge from a distance and in the most difficult position—viz., in the battery—whether he is doing well or badly. For instruction on the Range, sands such as those at Shoeburyness and a large front of the service 9-ft. × 9-ft. targets are the very best form of ground and target that can be devised; since the ground covered by the spread and the penetration of the bullets can be seen with perfect ease. The range party are in entire safety 150 yds. on either side of the target. To assist in judging the distances, pegs every 25 yds. should be driven in front and rear of the target (the 50's and 100's being made easily distinguishable either by size or colour); and a tall upher should be placed 100 yds. in advance, having 5-ft. and 10-ft. marks

throughout its length. Such precautions ought to ensure sufficient accuracy of judgment.

When this portion of the instruction has been thoroughly mastered, the next step is learning to appreciate the results obtained from the position of the battery; and here commences the most difficult as well as the most necessary part of the course. At first, ground and targets such as already recommended may be employed with advantage. The practice should be carried out with deliberation, and the whole squad—not the No. 1 only—should be required to record their judgment in a small note-book; each book should be carefully compared with the range Report, both by the observers themselves and by the commanding Officer or Instructor. By this means, instead of as at present each individual having two or three chances of judging, he would have 30, 40 or more; and both he would be able to see and correct his errors, and the commanding officer would have ample opportunity of selecting men on whose judgment he might safely rely.

The points recorded should be "under," "over," "right," "left," and "height above plane."

Little need be said concerning "under" and "over," except that when a time shell happens to be blind they should still be recorded, with "blind" in the column of remarks. A short graze will often account for a blind, the cause of which would otherwise be uncertain. With regard to "over," it may be remarked incidentally that whereas a shell "under" must in the case of a time fuze necessarily be an indifferent one, such need not be the case with all which range "over." The following table gives the distances at which a 16-pr. shell will, at different ranges, strike the ground beyond the target if it just touches the top in its flight:—

Range.	Distance beyond.		Range.	Distance beyond.	
	9′ × 9′	6′ × 6′		9′ × 9′	6′ × 6′
yds.	yds.	yds.	yds.	yds.	yds.
1000	34·0	22·7	2200	32·6	21·8
1200	33·7	22·5	2400	32·5	21·7
1400	33·5	22·3	2800	32·2	21·5
1600	33·3	22·2	3200	32·0	21·3
1800	33·0	22·2	3600	31·8	21·2
2000	32·7	21·8	3800	31·7	21·1

If a similar table were constructed for the 9-pr., the distances would vary for 9′ × 9′ targets from 34 to 31 yds.; for 6′ × 6′ from 22·7 to 20·9 yds.

The necessity of a careful judgment of the errors "right" and "left" is apparent when one remembers how small the cone of dispersion is in the present pattern of shrapnel, and how much therefore

of the effect of an otherwise good shrapnel may be entirely lost if such errors are not avoided. This is the only part of the question which is most easily settled from the actual position of the guns themselves.

Height above plane is a very important point. The best for each range has already been given at p. 185. When shell are made to burst closer up, a corresponding decrease in height must be allowed.

Unless the range has been verified, as suggested before, by percussion shell it will be almost impossible to judge whether incorrect height above plane is due to error in elevation or in length of fuze, or to a faulty burning of this latter; hence the chief difficulty in their use. When however the range has been verified, a high burst will without fail indicate a short, a low burst a long fuze.

If the ground should be of such a nature that the actual strikes of the bullets can be seen, the judgment of shrapnel is comparatively easy. Nearly half the cone should be seen to strike in front of the target, for unless such is the case the elevation is too great. When the object fired at is a body of men and the strikes cannot be seen on the ground, the fall of individuals or a movement of disquiet in the general mass will, if narrowly observed, afford a fair criterion of the practice.

When such helps as these cannot be obtained and it is therefore necessary to trust to simple observation of the burst of the shell in the air, this can be done far more easily and certainly from a point well to the right or left of the battery than from the guns themselves. Considerable advantage would be gained by placing a really good man in such a position.

As soon as fair skill is gained in judging shrapnel over the easy ground and at the distinct targets hitherto recommended, both ground and targets should be changed for others which will afford as nearly as possible the conditions of, and the formations incident to, actual service. Unless such is the case, it is not too much to say that not only may officers and N.C.O.'s fail to attain that skill in the use of shrapnel which results from a thorough knowledge of its effects, but that they even run the risk of misapplying it from arriving at conclusions the very reverse of the truth.

The ground should offer positions suitable both for attack and defence, so that both parts of the main question can be entered into; there should be space enough to manœuvre a few batteries in combined action; rough broken ground, walls, hedges, ditches, woods, and other natural cover should be obtainable, and in addition good sound ground for field works, shelter trenches, gun pits, &c.

The targets should consist of dummies representing Cavalry or Infantry taking every advantage of the cover that such ground as above described can afford, so as to imitate as far as possible the conditions of actual service.

The attack of a position, although it offers a task far more difficult than that of the defence, seems to have been to a certain extent lost sight of in the experiments referred to in this paper; in the case of nearly the whole of them the targets could only have represented an enemy attacking over very hazardous ground.

It would certainly be of immense advantage if on such a practice ground the question not only of artillery fire, but of the effect of other fire against artillery were worked out. If a few companies of Infantry were available to practice at dummies representing the guns and men placed in the various positions which the Artillery take up, not only would the Infantry obtain a target far more practical than any that they are at present allowed, but the Artillery would learn many a lesson of the greatest possible value. Such a course, too, would have the inestimable advantage of bringing different arms of the service together at really practical work.

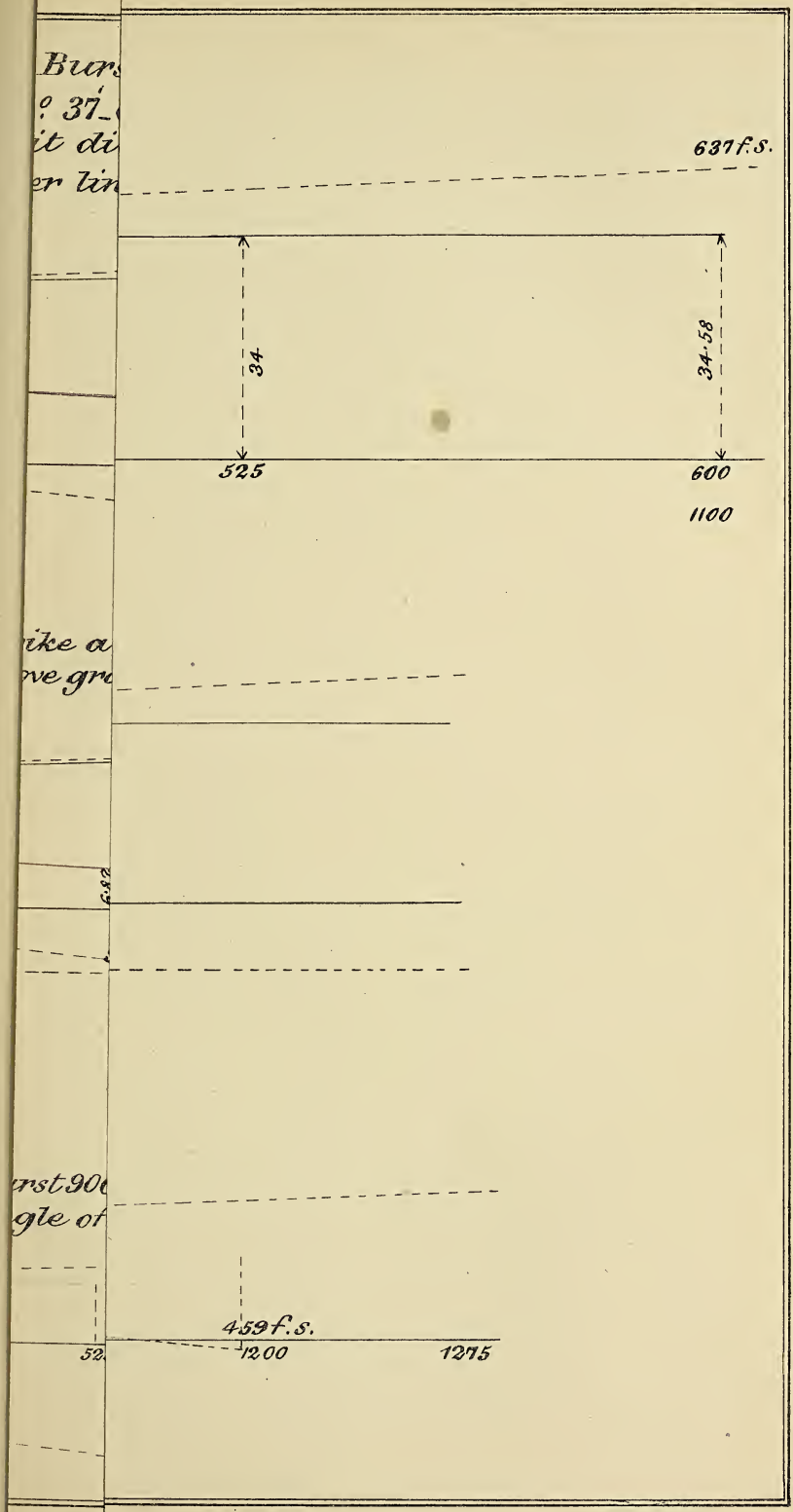
Officers of any one branch of the service are only too much inclined to undervalue the power of the others, and consequently to overrate that of their own; and this from the simple fact that their technical education is almost entirely confined to the manœuvres and work of their own arm. Undoubtedly an intimate knowledge of this is an absolute necessity; to make a thoroughly efficient officer, however, a general knowledge at least of the others is almost equally so.

All practice, other than that having for its object either the instruction of recruits or prize firing, should be to a certain extent experimental. It should have some object which either presents a difficulty, or about which there may be some doubt; and with a view of obtaining the most reliable results, the Officer commanding should be left at liberty to record them, either by individual shells or in large or small groups, as the occasion may demand.

It would be of great advantage if the Officers in command of districts were allowed a certain number of rounds per battery which they could use, without trenching upon the rather inadequate amount already at the disposal of Majors of batteries, for the purposes of inspection and for carrying out experimental practice either with single batteries or with a few brigaded.

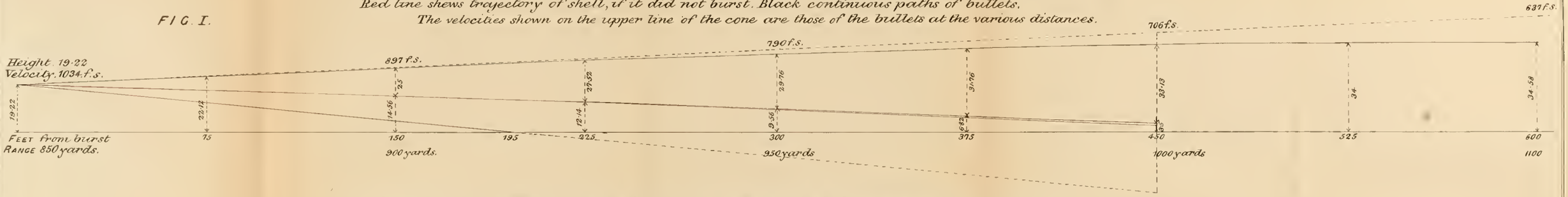
Of those who may have had the patience to follow the writer up to this point, many, he is afraid, will come to the conclusion that his bias in favour of time shrapnel is unduly strong. He cannot but admit the strength of his belief; but since it is the result of the actual observation of many thousands of rounds, and of the study of many carefully recorded Reports of practice, he cannot think that it is altogether unfounded. His object will have been entirely gained if the present paper should induce any officers, who may have the opportunity, to put any of the conclusions which he has arrived at, but from which they might be inclined to dissent, to the test of actual practice and to record the results for general information. Theories untried are valuable only as an introduction to experiment. No theory can be established as correct until it has been tested and its truth confirmed by exhaustive practical trial.

SHOEBURYNESS,
Dec. 1876.


637 f.s.
34
34.58
525
600
1100
459 f.s.
1200
1275

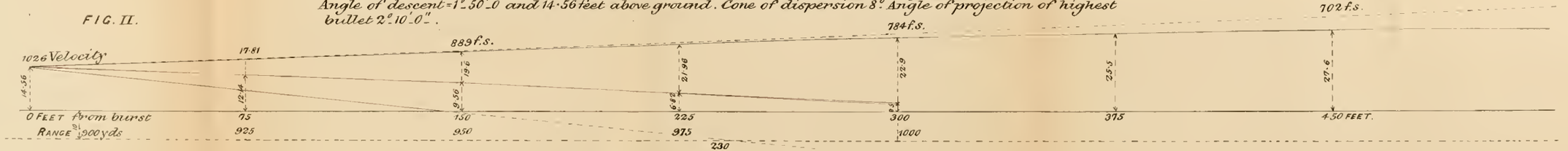
SECTION OF CONE OF A 16 Pr SHRAPNEL, Burst at 850 yards; elevation to strike an object 3·5 feet high at 1000 yds.
Angle of descent at point of burst = 1° 31'-0" Angle of cone 8° of projection of upper bullet 2° 13'-0" with horizon.
Red line shews trajectory of shell, if it did not burst. Black continuous paths of bullets.
The velocities shown on the upper line of the cone are those of the bullets at the various distances.

FIG. I.



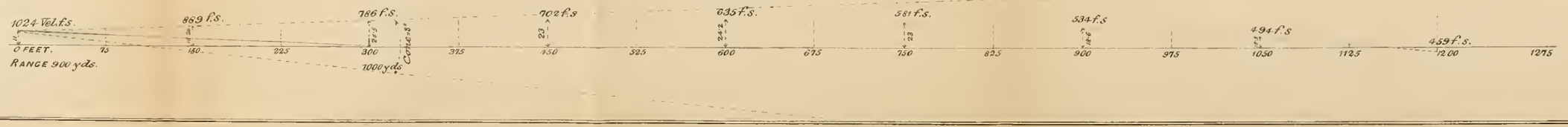
16 Pr SHRAPNEL. Burst at 900 yds. Fired to strike a target at 1000 yds 3·5 feet from ground. Has 1024 f.s. at burst.
Angle of descent = 1° 50'-0" and 14·56 feet above ground. Cone of dispersion 8° Angle of projection of highest bullet 2° 10'-0".

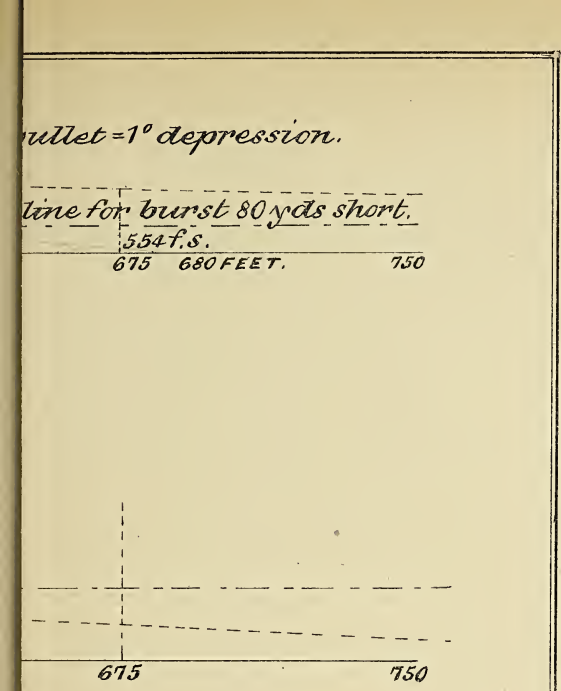
FIG. II.



Scale 75 feet = 1 inch.
Burst 900 yds. Range 1000 yds. Burst 100 short.
Angle of descent at 900 = 1° 50'. Angle of Cone = 8°. Angle of projection of highest bullet = 2° 10' depression.

FIG. III.




ullet = 1° depression.
line for burst 80 yds short.
554 f.s.
675
680 FEET.
750

675
750

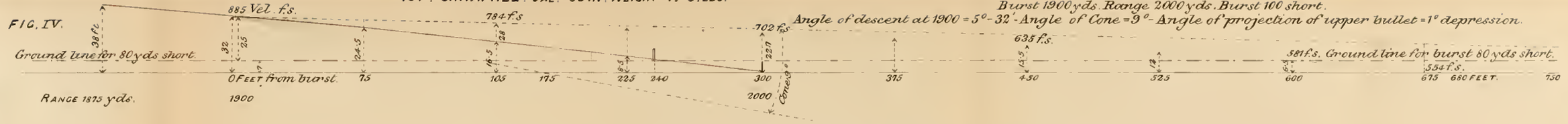
16 Pr SHRAPNEL. CAL. = 36 IN. WEIGHT = 17·5. LBS.

Scale 50 feet = 1 inch.

Burst 1900 yds. Range 2000 yds. Burst 100 short.

Angle of descent at 1900 = 5°-32'-Angle of Cone = 9°-Angle of projection of upper bullet = 1° depression.

FIG. IV.



Scale 50 feet = 1 inch.

Burst 2400 yds. Range 2500 yds. Burst 100 short.

Angle of descent at 2400 = 7° 50' Angle of Cone = 9° 30' - Angle of projection of upper bullet = 3° - 5' depression.

FIG. V.

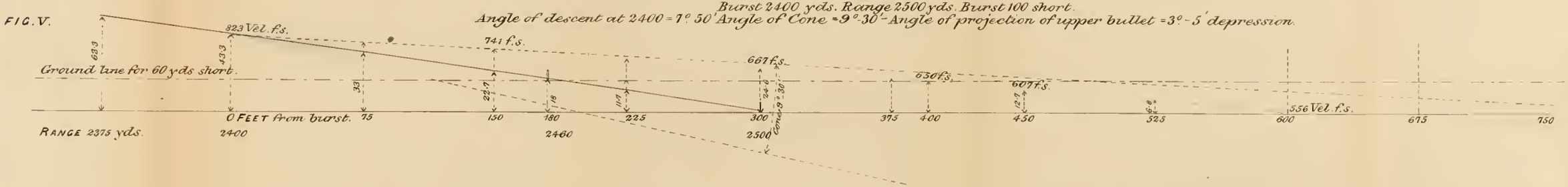


FIG. VI. 16 Pr SHRAPNEL. Range 2500 yds. Burst 60 yds short. 25.3 ft. above plane.

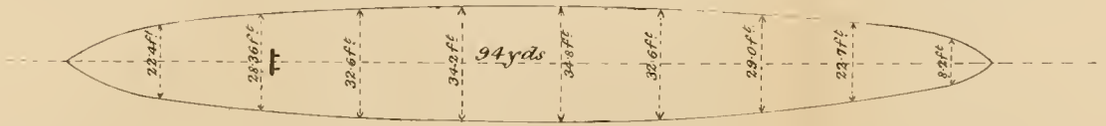


FIG. VII. 16 Pr SHRAPNEL. Range 2500 yds. Burst 100 yds short. 43.3 ft. above plane.

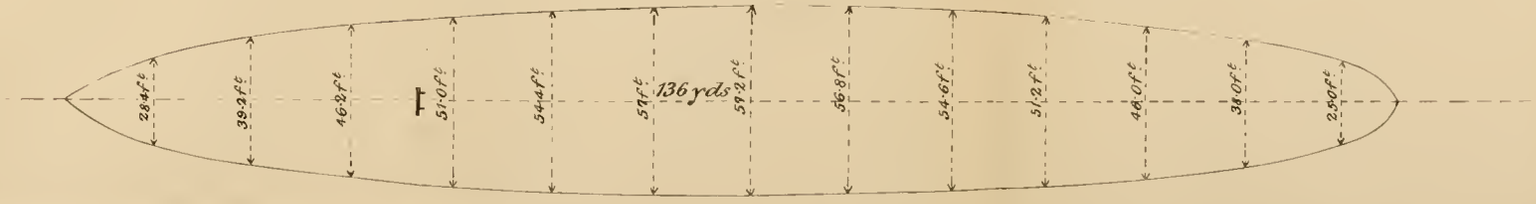


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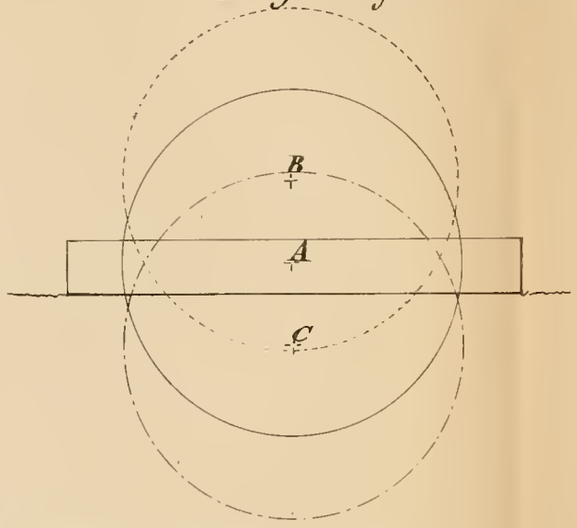
FIG. VIII.

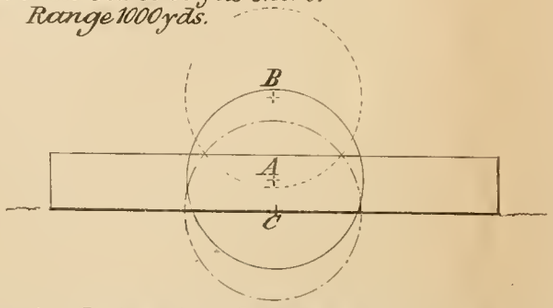
Target 56 f.t × 6 f.t
16 P.r Shrapnel burst 100 yds short.
Range 1000 yds.



A. Shell burst so that centre of cone & centre of Target coincide.
B. ------ ,, ------ 10 f.t above this trajectory.
C. ------ ,, ------ 10 f.t below ------ ,, ------

FIG VIII, a.

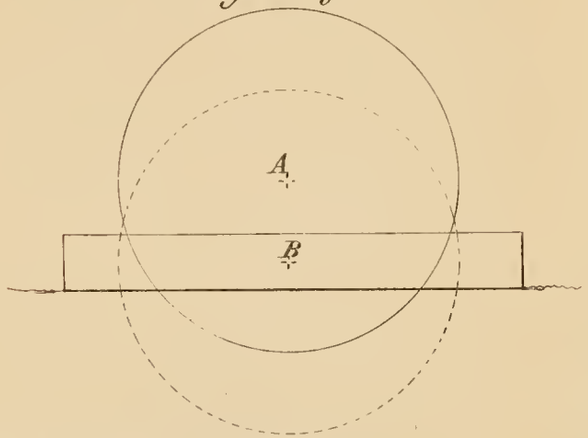
Target 56 f.t × 6 f.t
16 P.r Shrapnel shell burst 50 yds short.
Range 1000 yds.



A. Shell burst so that centre of cone & centre of Target coincide.
B. ------ ,, ------ 10 f.t above this trajectory.
C. ------ ,, ------ On plane.

FIG. IX.

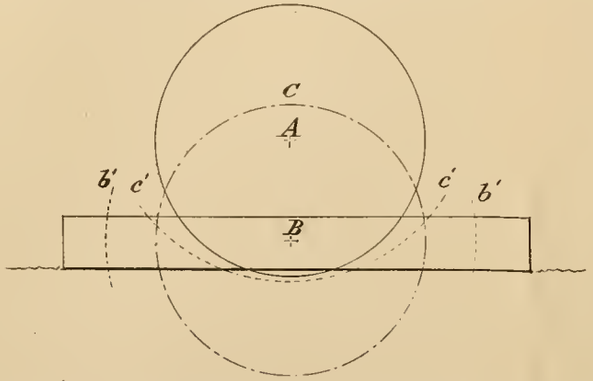
Target 56 f.t × 6 f.t
16 P.r Shrapnel shell burst 100 yds short.
Range 1000 yds.



A. Percussion shell after graze.
B. Time shell, centre of cone & centre of Target coinciding

FIG X.

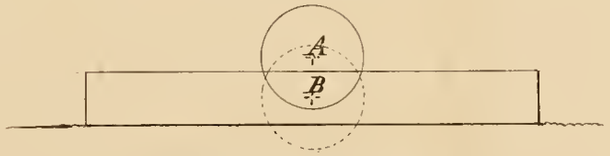
Target 56 f.t × 6 f.t
16 P.r Shrapnel burst 80 yds & 120 yds short.
Range 1300 yds.



A. Percussion shell burst 80 yds short.
B. Time shell 80 yds short. centres of cone & Target coinciding.
C. (c,c,) Percussion shell burst 120 yds short. (portion on or below Target only shown.)
B. (b,b,) Time shell burst 120 yds short, centre of cone & Target coinciding.

FIG XI.

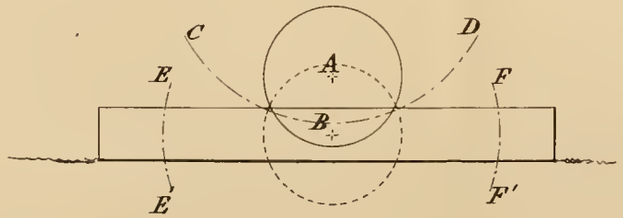
Target 56 f.t × 6 f.t
16 P.r Shrapnel burst 80 yds short.
Range 1600 yds.



A. Percussion shell.
B. Time shell.

FIG. XI, a.

Target 56 f.t × 6 f.t
16 P.r Shrapnel burst at 40 yds & 100 yds short.
Range 1600 yds.



A. Percussion shell 40 yds short.
B. Time ------ do ------ do ------
C.D. Percussion do ... 100 yds short
E.E, F.F, Time ---- do ---- do ----

HISTORICAL NOTICES OF THE ROYAL ARTILLERY.

[No. II.]

BY

MAJOR F. DUNCAN, LL.D., &c.,

Royal Artillery.

On taking over my duties a few weeks ago in the Royal Military Repository, I found a number of quaint old manuscripts, of which the attached is a specimen. It was dated in the year 1784—only a year after the signing of the Treaty of Peace at Versailles—and was deposited, and apparently in the first instance composed or arranged, by an officer who subsequently attained to the position of Surveyor-General of the Ordnance—Captain James Hadden. As this officer was afterwards chosen to command one of the first troops of horse artillery, on its formation, it may be assumed that he was one who was familiar with the movements of field artillery, and was not legislating (as so many men have to do) for individuals and circumstances of which he knew nothing.

To understand the paper, the reader must bear in mind that, in the days treated of, field artillery was represented mainly by *battalion guns,* and the drivers were *peasants* not *soldiers.*

It is interesting to find, under the duties of the No. 1, the gender of the gun already recognised as feminine. This recognition is no longer official, but his gun is "*she*" to the gunner of 1877 as emphatically as to his predecessor in the year 1784.

There is a refreshing frankness in the note attached to par. *H*; and the concluding sentences are worthy of a post-prandial oration instead of a grave drill-book.

F. DUNCAN.

DIRECTIONS

*For the Exercise of Artillery Field Pieces, or what is commonly called the quick Firing Motions.**

One Non Commissioned Officer and Thirteen Men are required to each Gun (or rather two Non Commissioned Officers when they can be spared and twelve men) they are posted in the following manner.

N.B. At Exercise, as well as upon Service, one Subaltern Officer is generally posted to every two Guns and a Captain to four six or eight Guns.

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* The spelling and punctuation of the original MS. have been retained.

A. One Non Commissioned Officer to superintend the whole, his particular Charge is to point the Gun to the Object fired at, by moving the screw, so as to make her fire higher or Lower, and in directing the Man who steers to traverse her to right or Left by the handspike; his post is on the left of the Gun, behind the dragropes, shifting his situation as occasion requires so as to be able to observe the Effects of the shot on the object fired at.

B. One man or rather a Non Commissioned Officer when he can be spared, to direct the Gun by Steering or Traversing it, his post is on the left, at the Extremity of the Trail of the Carriage, with his right hand on the traversing hanspike; when the word *fire* is given he is to stand clear of the Recoil by falling back on the left heel, and in advancing he is to Ease the Men as much as possible; *I.E.* those who draw the Gun, by pushing her forward and by raising her Trail now and then from the Ground.

C. A Man to fire, whose post is on the left of the Gun, he is to use a portfire; he is to keep his Eye fixed on the Man who rams home, with the portfire in his right Hand, extending it from him at Arms Length, except just at the instant he fires, which is done by touching the lip of the cup of the Tube, taking Care not to lay the portfire over the Hole of the cup.

D. A Man to serve the Vent, his post is on the right of the Gun, opposite to the man who fires, he is to be furnish'd with a Tin Box, which may contain One hundred Tubes, tied round his Waist; as soon as the Gun is loaded he puts in the Tube, and is to be carefull not to do it before; after he puts the Tube into the Vent he covers it with his left hand, till' the word fire is given when he steps back with his left foot keeping his right foot which should be always without the wheel, fast, as soon as the Gun is fired he is to Step up with his left foot and cover the vent close with his left Thumb while *F* is spunging and loading, which done, he introduces the Tube with his right hand as before, covering it with his left, he should always be furnished with a claw Hammer, two Pinchers and a Drill and Gimblet with which he may clear the Vent, when it is clog'd by a Tube remaining in it or otherwise.

E. A Man to load, whose post is on the left of the Gun close up between it and the Wheel of the carriage with his right foot advanced; as soon as the Gun is spunged he introduces the Cartridge into the chace which he receives while the Gun is spunging from the Man who serves with Ammunition, in firing standing he receives the Cartridge over his right shoulder by making a small inclination of his Body to the right without moving his foot, and in firing advancing and retreating, he receives the Cartridge over his Left shoulder, making a half face to the left for that purpose.

F. A Man to ram home the charge and to spunge, his post is on the right of the Gun, close up between it and the wheel of the Carriage and opposite to the man who loads, he carries the spunge in a perpendicular Posture at his right Side, touching the Hollow of his Shoulder, the rammer hand just below; his right hand which is extended downwards close to his thigh, this brings the spunge a little above his head with his left hand across his Breast laying hold of the spunge Staff with it about the middle, his left foot advanced before his right foot, making a full face to the left, in which motion he lets the spunge fall down in a horizontal posture, with the spunge head close to the Muzzle of the piece: having spunged the Gun which is done by thrusting the Spunge head home the full Length of the Chase, and giving it one turn quickly, he then withdraws it and waits till the man who loads introduces the Charge which he rams home once, springing out the rammer

briskly and seizing it with the left hand, and falling back into his Place with the Right foot behind the left heel, bringing the spunge to his right Shoulder in a perpendicular manner as already directed, gives the word fire immediately, upon the Explosion he spunges as before.

N.B. Those two men, vizt. he who loads and he who rams home are to be particularly carefull to keep their Bodies at all times out of the line of fire, the man who loads advances with his left foot, upon his right heel making a full face to the right, at the same time that the man who rams home makes a full face to the left, which motions those two men are to do together.

G. A Man to serve with Ammunition, his post is on the left of the Gun, just without the Wheel of the Carriage with his Back to it, he carries a Leathern Pouch in which he should never have more at a time than three charges, slung over his right Shoulder, securing the Lid of the Pouch close with his left hand, except when he hands out a Cartridge to the man who loads, which he is to do while the Gun is spunging; and that with great Caution, this is done by his making a half face to the right upon both Heels, to meet the man who loads, who at the same time makes an Inclination to the right to receive the Charge as has been said before.

H. A Man to supply Ammunition from the Tumbrel or place where the Ammunition is put, which should be in as convenient a place as can be found, at a proper distance from the Gun, he carries a Leathern Pouch slung round his right shoulder, which he supplies from the Tumbrels as often as is necessary and changes the pouch with the man who serves with ammunition as often as is wanted.

N.B. In actual Service a Non Commissioned Officer and eight or ten men from each Battalion of Infantry are generally attached to its two guns, who are to assist in taking care of the Ammunition at the Tumbrel or Waggon, the Limbers and the Cattle, and in preventing the Drivers from running away while the Artillery are employed on the Batteries.

Six men for the Dragropes, who lay hold of the wooden pins, three of which are fixed at an equal distance in each Rope; in firing standing they draw up and dress in a Line with the Axletree of the carriage, and are to be attentive to the word of command or Signal to shift the ropes and to advance or retreat. In advancing the two men who draw at the outside ends of the Ropes should keep well extended at Equal distances from the Gun and about three fathoms from each other, so as to be far enough out of the reach of Explosion; when the word or Signal is given for retreating the two men at the innermost Ends must shift the Ropes from the Hooks at the Ends of the Axletree quickly, upon which the two Men who in advancing were the outermost, fix their End to the Hook at the End of the Trail, always facing inwards, and in retreating they are to keep well extended so as not to be in the way of the Recoil.

When the men exercise without powder, a Large wad of Hay, Straw or Junk should be ram'd Home, to save the rammer head, and before Exercise with powder or going on Service, the Gun should be well spunged and the Vents and screws cleared and Oiled.

When the men are taught to perform all the motions so perfectly that powder may be used, too much care and precaution cannot be observed in the Beginning, from firing verry slow, they are to proceed Gradually as they grow more perfect; in firing quick as possible never neglect to spunge after each Discharge.

The men must be made perfect in firing Standing, before they are suffered to fire

retreating, the firing in advancing being the most dangerous should be the last practiced; in all field Exercise Tin Tubes must be used, and on all other occasions when they can be had.

Cartridges for exercise as well as all others for Field services should be made of flannel choked with Cat Gut.

A Small Quantity of powder will suffice for practicing the quick firing motions, Eight or Ten Ounces is sufficient for a light six pounder and so in proportion for other Guns.

In firing quick for any Length of time, the Bottom of the cartridge may remain in the Piece, in which case recourse must be had to the Wadhook, it is to be observ'd that every man belonging to the Artillery, even the Drummers must be taught the several motions in the Exercise as well as every other Duty or manouvre which may required or can possibly occur in actual service, pick'd men should not be allotted for particular services but they men are to be often changed and to perform all the Duties in the exercise alternately, nevertheless, Officers should observe and mark those men who are most active, attentive and carefull in ramming Home and Loading, and in firing that such may be employed in those particular services, or in anything else in which they excell on important Occasions.

It is strictly enjoined that the men must never be suffered to turn their Backs on an Enemy in retreating or on any occasion, on the Contrary they are to look at and make a full face to the Enemy, as much as their respective Duties can admit.

EXTRACT FROM REPORT ON THE BELGIAN SIEGE AND GARRISON ARTILLERY, BY MAJOR AND BT.-LT.-COL. H. BRACKENBURY, R.A., DATED 9TH SEPTEMBER, 1876.

[COMMUNICATED BY THE DEPUTY-ADJUTANT-GENERAL, R.A.]

Practical instruction of the Belgian artillery.

Although the foregoing remarks comprise all the subjects named in my instructions, I may, perhaps, be allowed to add a few notes on the practical instruction of the Belgian artillery.

The polygone of Brasschaet.

At Brasschaet, about 12 miles from Antwerp, is situated the artillery instructional establishment, which comprises a school of gunnery (école de tir), for officers and non-commissioned officers, and a practice ground (Polygone d'exercice), for field and siege (garrison) batteries.

Description of the establishment and practice ground.

A large tract of sandy barren heath, slightly undulating, about 3000 yds. in length, and increasing in breadth from about 400 yds. at the southern end to 1000 yds. at the northern end, is enclosed and surrounded by plantations of young timber. At the southern end are the buildings, including quarters for the staff, barracks for officers and men, and stables for the horses of the batteries under instruction, mess rooms for officers and non-commissioned officers, and a few class rooms.

The remainder of the space is occupied by the practice ground, upon which are constructed works representing portions of permanent works, casemates, land and coast batteries, and works representing the approaches and batteries of an attack.

Commandant.

The establishment is under Major-General Terssen—an officer of scientific attainments, who is at once Commandant of the Ecole de Tir and of the Polygone d'Exercice and member of the Permanent Committee of Experiments with rifled artillery.

Division of the year into three parts.

The year is divided into three parts of four months each.

Course of gunnery for officers and N.C. officers.

Four months are devoted to a course of gunnery for officers and non-commissioned officers. Each regiment of field or siege artillery sends yearly three officers and three non-commissioned officers to this course. The school is but recently established, and the instruction of the officers has commenced with the Captains Commandant, and will proceed downward in the scale of rank.

Practice of the troops.

Four months are devoted to the practice of field and siege batteries. Every battery in the army attends the Polygone every year for 17 days. Each battery has at least three different kinds of practice, of at least 50 or 60 rounds each.

Experiments and vacation.

The remaining four months are devoted to the experiments of the Permanent Committee, and to the vacation of the Staff.

Source of the following remark.

I had no opportunity of learning the programme of the course of gunnery for the officers and non-commissioned officers; but if it may be judged by what we learnt of the practice of the batteries, its whole bearing would be eminently practical. We were fortunate enough to find the practice by siege

batteries still going on, and from what we then saw and subsequently ascertained, the following remarks are taken :—

Siege batteries perform duties as in war, in a permanent work.

Each siege battery goes down in marching order to a work representing a portion of the ramparts of a fortress, and there performs the duties for 24 hours, exactly as though it were on duty in a front of fortification in time of war. It mounts the guns, brings up stores and projectiles, and fills the expense magazine in the reverse slope of the ramparts. It mounts guard, and has its look-out man always in his place, as he would be in war.

Practice from battery at siege works.

At an uncertain hour a petard is exploded in one or other of the batteries in the parallels of the siege works thrown up against the fortress battery; then another representing the fire of guns. The officers have then to open fire upon the battery thus indicated, and if guns are mounted there to endeavour to dismount them, whether in embrasures or behind a solid parapet. The first shot should be fired within a quarter of an hour of the explosion of the petards. The range may or may not be known, but the exact elevation and deviation required must be found, and it is recognised that on no two days will these be precisely the same, in consequence, probably, of changes in atmospheric conditions. These the troops are taught to find by their fire, which should always commence short of the object fired at, the elevation being gradually increased. When the exact elevation is apparently attained, it is recognised that according to theory of probabilities one shot in a certain number will fall short, and if this does not happen the elevation is apparently too great, and a trial shot is fired at a lower elevation.

System of laying by pickets in covered way.

Pickets painted white are placed in the line of fire in the covered way, and when the real elevation is ascertained, and the gun laid by it, the tangent scale bar is raised, and the elevation noted to lay on a mark on the picket. After this, the laying is always on the pickets, which offer an easy mark, instead of on the scarcely discernible object which a low siege battery presents at a range of from 1000 to 2000 yds. Fire is continued at night, the gun being laid on a light placed on the picket. We saw good practice at 1800 yds.

System of laying with "ligne de mire renversée."

There is another system of laying the gun taught—viz., that known as "ligne de mire renversée." The No. 1 lays from a small wooden eye-piece placed on the muzzle, the bar of the tangent scale serving as a sight, at a mark on a picket placed on the line of fire, in rear of the battery. We saw excellent practice of this kind at 1200 yds.

Practice from coast battery at moving target.

Firing is also carried on from a coast battery at a movable target representing a ship in motion.

Siege batteries go on duty in the trenches.

A battery sent on trench duty brings up through the trenches its siege guns and mounts them in the night. Its programme includes firing to

Practice from siege batteries at concealed targets.

destroy targets concealed behind a glacis, by curved or indirect fire at various ranges.

Practice varies yearly.

The practice for each battery varies each year. I append a programme for the year 1876.

Examples of field artillery practice.

As examples of the system of teaching the field artillery, the following may be given :—

Practice at a moving column of infantry.

A railway with a gauge of about 40 ft. is laid down for a length of about 800 yds. On this, by an ingenious system, is moved by a fixed capstan and chains a target representing two sections of infantry of about 20 files each, at open column, painted to look like troops under arms. The railway runs over undulating ground. A battery trots up to the practice ground from its stables, and halts. Presently, at an unknown range, appears a small column of infantry moving directly towards, or obliquely towards, or from the battery, which comes into action against the column, on the heads of the imaginary troops emerging from a hollow, and continues in action till they have, at an increased pace, sought and found shelter.

Practice at infantry who lie down under fire.

Or a battery comes into action against targets which, after a round or two has burst close by them, imitate the movement of troops by lying down; and the battery has to continue its practice against an enemy unseen, though known to be present.

Range found by observing effect of shell.

No range-finder is in use, either for garrison or field artillery. Some have been tried—Gauthier's for garrison guns, Nolan's and Boulengé's for the field; but none has been adopted, and probably none will be, as many officers avow their opinion that no instrument is equal to a shell with percussion fuze watched by a trained eye. Much attention is paid to the training in finding the range by practice.

System of testing the power of aiming correctly.

It is recognised that only some men can lay a gun well, and that even among good aimers each man has his own personal equation of error. The Prussian instruction sight is used for testing a man's aiming power. This sight has slides carrying the eye-piece, moving vertically and horizontally, and each furnished with a vernier. The soldier lays the gun, the instructor notes the readings of the verniers, which the man does not see, and throws both slides out of gear. The soldier lays again, by replacing the slides, not by moving the gun. The verniers are again read, and again thrown out of line; and this operation is repeated a third time. If a man lays three times exactly alike, he is considered to have a great power of aiming, though he may not have laid perfectly truly on the object, owing to his personal constant error of vision.

System of controlling the practice and using it for instruction.

All practice is watched in the battery by an officer of the Staff of the Polygone, trained to observe and judge accurately. Such an officer is also on the range party. The officer commanding the battery firing makes his own practice table, judging the effect of his shots; and after the practice his table is compared with that of the range party and the notes of the Staff Officer in the battery, and an instructor points out the errors made, explains their causes, and gives practical hints and suggestions.

Prizes for good shooting.

No careless practice is allowed. Prizes are given for good shooting, both in the form of distinguishing badges on the arm for marksmen, and money prizes for the battery.

Practical aim of the instruction.

Thus every encouragement is given to the artillery, both field and siege, to learn this most important part of their profession; and the whole object of the instruction seems to be to prevent useless expenditure of ammunition, and to teach men to make thoroughly good practice under conditions as nearly representing those of war as it is possible to obtain in time of peace.

EXTRACT FROM REPORT ON THE BELGIAN FIELD ARTILLERY, BY MAJOR AND BT.-LT.-COL. H. BRACKENBURY, R.A., DATED 16TH OCTOBER, 1876.

Practice carried on at Brasschaet.

In a report recently made by me upon the Belgian garrison and siege artillery, I drew attention to the practical nature of the practice carried on each year by the batteries both of siege and field artillery. I may, perhaps, before closing this report, be again allowed to draw attention to the practice of the field artillery.

Every battery carries on yearly practice at the Polygone of Brasschaet, where it passes three weeks for this purpose. Economy being of great importance, the object is to get the greatest amount of instruction out of the smallest amount of ammunition.

Only 20 rounds per gun allowed.

I find that in 1876, 20 rounds per gun only were allowed.

Programme for 1876.

The following are extracts from the orders for the year 1876 :—

"Each field battery and battery of horse artillery will carry out the following programme :—

"1. Practice for the purpose of regulating the guns, with shells not filled. (Tir de réglage à obus d'exercice.)

"2. War practice.

"3. Experimental practice with reduced charges.

"Regulating practice.

"The 'regulating practice' will be carried out by all the six guns of each battery, with 10 rounds per gun, at a range of 1400 mètres (1531 yds.) From the results of this practice, as compared with those obtained in 1875, the Commandant of the School of Practice will decide whether the existing classification of the guns according to their shooting should be retained or modified.

"This regulating practice precedes the war practice.

"War practice.

"The war practice will be carried out after a march of about 9 miles, with 4 guns per battery, and 10 rounds of common shell or shrapnel per gun. This practice will be at objects as nearly as possible resembling what would have to be fired at in war, including moving targets; and officers commanding batteries will not know the nature of the object to be fired at until they arrive on the ground.

"The ranges will vary between 800 and 2500 mètres (875 and 2734 yds.)

"Practice with reduced charges.

"The practice with reduced charges will be carried out with 2 guns per battery, and 10 rounds of unfilled shells per gun. This practice will be conducted according to a programme made out by the permanent Committee of Experiments, with a view to ascertaining, as regards field guns, what are the probable deviations with reduced charges, in order to complete the range tables for these guns. If possible, practice with reduced charges will be carried on consecutively on the same day by the three

batteries present together at the Polygone; so that 60 rounds may be fired under the same conditions.

"The first war practice with field artillery, and the first siege or garrison practice for the purpose of dismounting guns in each period,* will be carried out in the presence of all the officers belonging to the batteries in camp without exception; and each practice will be followed by a lecture. "Lectures given on the practice.

"Other lectures upon the questions under study will be given during each period.

"The Commandant of the Polygone will bring together all the officers at the end of each period, and will make them discuss in his presence various portions of the practice carried out.

"Practice will be carried out by batteries under the direction of their own commanding officers, and in the presence of a member of the Committee of Experiments, whose duty is to ensure that the principles taught in the School of Practice are carefully observed. "Staff officers superintend practice.

"The reports to be sent in after the practice will be prepared by the officers of the batteries, under the direction of their commanding officers. "Reports prepared by battery officers.

"The officers on the range will, however, always be accompanied by a captain or lieutenant attached to the Committee of Experiments, who will satisfy himself as to the exactitude of the observations taken, and will be responsible for their correctness. The reports will be prepared in conformity with the specimen reports taught in the School of Practice. "Staff officer on the range.

"Every officer not on duty will attend at all practice." "All officers attend practice."

(Thus each officer has the advantage of attending at the practice of two other field batteries besides his own.)

In addition to the actual practice, there are competitions in laying guns, and distinctive badges and money prizes are given to the best marksmen. Competitions in laying guns.

Competitions within each battery are carried out under a committee appointed by the officer commanding the regiment, and consisting entirely of officers belonging to other batteries. These take place at the stations of the batteries before their departure for the Polygone.

Then, at the Polygone, the marksmen of all the batteries present each period compete together for the distinctive title and badge of "first marksman."

The officer commanding the battery himself gives in to the Commandant of the Polygone, after each day's practice, the following reports:— Reports of practice.

1. Procès Verbal et Justification du Tir.
2. Bulletin du Tir.
3. Tableau des Résultats du Tir.

These reports are elaborately detailed.

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* A "period" consists of three weeks. Three field and four siege batteries are present together at the Polygone during each period.

Procès Verbal.

A. The *Procès Verbal* gives the following in great detail:—

1. Object of the practice, nature of target, distance (estimated, found by shells, &c.)
2. Material used and ammunition.
3. State of atmosphere.
4. Behaviour of the guns.
5. Method of carrying out the practice (number of rounds; range, how found; changes made during practice, &c.)
6. Results of practice (hits, misses, failures in bursts, &c.)
7. Point of aim, point of impact.
8. Length of time occupied in practice.

Justification du Tir.

B. Justification du Tir.

This is an amplification of the preceding, and contains:—

1. Object of the practice (bring out the tactical object of the practice without speaking of the material means used).
2. Explanation of the method proposed for carrying out the object of the practice. Tactics adopted.
3. An elaboration of 5 in the Procès Verbal.
4. Do. of 6.
5. General observations on the practice, if there is anything worthy of remark.

Bulletin du Tir.

C. Bulletin du Tir.

This is a table showing by strokes in various columns the hits and the misses subdivided into right, left, under, over, &c.; with a column of observations showing the number of trial shots, the number of splinters or bullets in the target, the premature bursts in the air or in the bore, the late bursts, and blind shells.

Tableau des Résultats.

D. Tableau des Résultats, et Représentation Graphique du Tir.

This is really a table carefully prepared from the observations of the range party.

Représentation Graphique.

The Représentation Graphique shows every shot fired, numbered in order. It comprises an elevation, plan, and profile of the target, with the point of impact of every round fired.

Reports checked.

These reports are checked by the independent observations of the Staff Officers present with the battery and on the range, and give to the Commandant the materials necessary for a short practical lecture upon the practice.

Value of tactical instruction.

I trust I shall not be doing wrong if I express my opinion that while in officers, men, horses, and material the British field artillery is without rival among any of those foreign powers whose artillery I have seen, it is yet behindhand in the practical instruction of its officers and men in the tactical use of their weapons in the field; and that something may be learnt, even from so small a country as Belgium.

Value of regularly established Polygones.

The value to both field and siege artillery of regularly established Polygones cannot, I think, be over-estimated. It is not merely in carrying on practice on broken ground, under varying conditions, that the advantage of a Polygone is found; but in the fact that such practice can there be carried on under the careful supervision of officers selected for their practical experience, and trained by the constant observation of practice to the greatest accuracy of judgment. To an artillery using time fuzes, and therefore less able to correct its errors by observation of the bursting of its shells, the superintendence of such skilled officers appears even more necessary than to an artillery using only percussion fuzes.

The Polygone of Brasschaet is very confined in its area; the necessity for economy limits below what is desirable the amount of ammunition expended; but yet it is not difficult to believe what Belgian artillery officers say—that the establishment of this Polygone with its School of Practice has doubled the fighting value of the Belgian artillery.

NOTES

ON

THE FIELD ARTILLERY OF ITALY.

TRANSLATED FROM THE SPANISH BY

LIEUT. J. C. DALTON, R.H.A.

Translator's Preface.

This article is translated from the Spanish "Memorial de Artillería," Feb. 1877, but the original appeared last December in the Italian "Revista Militare."

I have given the tables as I found them, with the exception that all measurements, &c., have been converted into English measure. I cannot, of course, vouch for the accuracy of the tables, as I have only been able to verify them as regards the English and Italian guns, and in the latter case I found that the figures corresponded with those given by Major-General H. H. Maxwell, C.B., in his article on the 7^{c} Italian gun, in Vol. IX., No. 7, "Proceedings, R.A. Institution," which article describes the gun in question and all pertaining to it very fully, and compares it with our 9-pr. M.L.R. gun of 6 cwt.

Ballincollig,
June, 1877.

The Italian field artillery of the present day consists of two classes of ordnance—viz., the breech-loading rifled gun of 7·5^{c} calibre (2·95 ins.), and the muzzle-loading rifled gun of 12^{c} (4·7 ins.)

The B.L.R. Gun of 7·5^{c}.

This is one of the most notable guns produced by artillery science within the last three or four years.

It discharges three classes of projectiles:—

(1) Common shell, weighing 3·7^{k} (8·2 lbs.), which breaks up on bursting into an average number of 24 fragments.

(2) Shrapnel shell, containing 100 bullets, and weighing 4·2^{k} (9·37 lbs.)

(3) Case shot, containing 61 balls, and weighing 4·1^{k} (9·1 lbs.)

The common shell would be employed at ranges varying from 2000 to 3600 mètres (2187 to 3936 yds.) exclusively against moving objects, and also against objects which offer a certain resistance—such as gates, walls of enclosures, country houses, &c. If the object is very extensive—as, for example, the camp of a division—the enemy may be harassed at a range of 5000 mètres (5467 yds.); but only in very rare cases would such a long range be employed.

At ranges under 2000 mètres (2187 yds.) common shell could always be usefully employed against any object whatever; but in the case of troops under cover, lines of skirmishers, or artillery either in motion or in action, it is preferable to employ shrapnel.

Case shot is for short distances, and to repel sudden attacks on the battery; it is of no value at distances greater than from 300 to 400 mètres (328 to 437 yds.), and it is consequently very rarely employed.

The following is a table showing the effect produced by the different species of projectiles :—

TABLE I.

Range.	Common shell.					No. of shrapnel bullets and fragments in 3 targets, 22 ft. apart, 10′ × 6′.	Case shot, 10 rounds. No. of balls placed in the target.
	Mean derivation.		Space struck at height of 5 ft. 11 ins.	Per-centage of hits on a company.			
	Horizontal.	Vertical.		Deployed.	Close column.		
yds.	ft.	ft.	yds.				
109 ...	—	—	—	—	—	—	389
219 ...	—	—	—	—	—	—	309
328 ...	—	—	—	—	—	—	240
437 ...	—	—	—	—	—	—	207
547 ...	1·7	1·8	103·0	100	—	101	116
875 ...	1·8	2·3	54·6	95	—	—	—
1093 ...	2·7	2·9	39·3	83	95	125	—
1313 ...	3·4	3·6	30·5	66	86	—	—
1640 ...	4·2	4·7	22·3	45	70	67	—
1968 ...	—	—	17·0	29	55	—	—
2187 ...	4·8	8·1	14·5	23	47	57	—
2406 ...	—	—	12·7	—	41	—	—
2734 ...	—	—	10·1	—	34	—	—
3062 ...	—	—	7·5	30	—	—	—
3280 ...	—	—	7·0	—	—	—	—
...	...	...	...	...	...	...	...
5640 ...	16·4	128·0	—	—	—	—	—

When these experiments were made, the graduations of the time fuze for the shrapnel shell had not been definitely settled.

At the extreme range—viz., 5640 yds.—the sides of the rectangle which contains all the hits are 23 and 167 ft.

It is very plain that at 547 yds. range no troops could possibly remain in position under the fire of the gun of 7·5^{c}. At 1093 yds. no column could deploy, whatever arm of the service it belonged to. If the ground were favourable, a column might attempt to advance very rapidly, but when deployed it would receive 83 per cent. of the fragments, and in close column 95 per cent. These figures hold equally good for cavalry and artillery. At 1640 yds. artillery would experience great difficulties in deploying and in coming into action, and infantry, in advancing in column of companies; the latter would receive 70 per cent., and the former 50 per cent. of the hits.

At 2734 yds. only could the battalion march in column with any security. The 7·5^{c} gun can therefore open an effective fire with common shell against a regiment in line at 1640 yds., and in column at 2400 yds., and against a battery at 1968 yds.

When opposed to the fire of shrapnel shell, the movements and positions of the enemy under the above-mentioned conditions would be still more difficult and dangerous.

The experiments made with case shot justify the limits that have been assigned, and suggest the importance of trying to obtain a shrapnel shell which would be more effective at short distances. This does not appear to be a difficult problem to solve.

It is true that these results are not based on actual experience; but the last wars have confirmed the theories founded by these results, and the fire of the Prussian artillery was just as destructive, if not more so, than theory led them to expect; and for accuracy of shooting their artillery is inferior to the Italian gun of 7·5^{c}.

M.L.R. Gun of 12^{c}.

The other Italian field artillery gun is the muzzle-loading rifled gun of 12^{c} (4·7 ins.) calibre.

It discharges three sorts of projectiles—viz., the common shell of 11·136^{k} (24·3 lbs.) weight; the shrapnel, containing 270 bullets, and weighing 12·68^{k} (28 lbs.); and the case shot, containing 41 balls.

This gun fires common shell by *direct fire*, with elevation; it fires shrapnel and case shot *point blank*.

With *direct fire* the common shell ranges to 3280 yds., beyond which curved fire must be employed, and is not good. The fire is very effective, but as it is not very exact, it does not do to employ it at more than 2187 yds. range, except at very large objects. Up to this limit good results would be obtained against columns of at least one battalion.

By employing curved fire from this gun against villages, they may be set on fire and destroyed; and against fortifications the *matériel* may be seriously damaged, and the place rendered untenable. In fact, with the 12^{c} gun a breach can be made in any ramparts, at distances varying from 328 to 1000 yds., and in a fairly short time.*

There are no certain details as to the results of the shrapnel fire from this gun; but it should be very effective at 1093 yds., because at this range the great defect of this gun—viz., inaccuracy—is not appreciable, and is compensated for by the enormous cone of dispersion of the 270 bullets.

Fire from case shot from this gun is very good at distances of 219, 328, 547, and 656 yds., if the ground be favourable—such as macadamized roads, &c.

We have spoken of this gun of 12^{c} because it is still actually in the service, but it is to be shortly replaced by a steel gun of 8·7^{c}, which for accuracy of fire, and in all other particulars, is equal, if not superior, to all the similar guns now used by the other powers that have re-organised their artillery—viz., Austria, Germany, and France.

It will be interesting to give a comparison of the armaments of the

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* This appears rather a bold assertion. The words of the original are:—"Con el cañon de 12^{c} se puede abrir brecha en *cualquier* muralla, á distancias, &c." One must not take it too literally. However, as the gun will soon be obsolete, these details are not very important.—J. C. D.

principal field artilleries of Europe. The following tables have been taken from a Russian artillery periodical :—

TABLE II.

Guns.

Countries.	Designation of guns.	Weight. cwt.	qrs.	lbs.	Calibre. ins.	Initial velocity. f.s.
Austria	4-pr.	9	2	10	3·4	1551
	8-pr.	9	2	24	3·9	1125
England ...	9-pr.	6	0	0	3·0	1391
	16-pr.	12	0	0	3·6	1355
	25-pr.	18	0	0	4·0	—
Germany ...	8c	7	2	20	3·0	1522
	9c	8	3	13	3·4	1459
Italy	7c	6	0	3	2·9	1312
	9c*.....		—		3·4	1538
Russia	4-pr.	6	3	3	3·4	1000
	4-pr.	9	2	19	3·4	1557
	9-pr.	12	1	0	4·2	1059
France	5k	9	1	12	3·0	1367
	7k	12	3	6	3·3	1279
Switzerland	8c	8	2	3	3·3	1297
	10c	12	2	3	4·1	1303

* This gun is about to be adopted in place of the 12c gun. (*Vide ante.*)

TABLE III.

Projectiles.

Countries.	Common shell. Weight. lbs.	Fragments weighing over ½ oz.	Shrapnel. Weight. lbs.	Bullets.
Austria	13·9	60	—	—
	14·4	60	16·37	140
England ...	9·1	36	9·80	63
	16·1	—	17·90	128
Germany ...	11·0	30	12·16	122
	15·4	35	18·03	209
Italy	8·1	24*	9·37	100†
Russia	12·6	25	14·43	105
	13·0	50	13·06	150
	24·3	30	29·86	210
France	8·8	—	—	—
	15·4	54	—	—
Switzerland	12·2	36	12·34	130
	17·2	—	20·45	130

* These fragments each weigh over 3½ ozs. † 27½ to lb.

TABLE IV.

Mean Derivation.

Countries.	Calibres.	Ranges.	Mean derivation.	
			Vertical.	Initial.
		yds.	ft.	ft.
Austria	4-pr.	1166	2·7	1·8
		2367	6·7	7·3
		3500	11·3	13·4
	8-pr.	2367	21·3	12·9
		3500	65·0	30·6
England	9-pr.	1166	3·2	—
		2367	10·8	8·3
		3500	33·2	14·5
	16-pr.	1166	1·5	1·9
		2367	8·2	4·8
		3500	17·7	8·4
Germany	8c	1166	3·8	4·4
		2367	13·5	9·5
		3500	40·6	2·0
	9c	1166	3·4	3·4
		2367	13·5	9·5
		3500	33·7	18·4
Italy	7c	1166	2·6	—
		2367	11·6	—
		3500	31·9	—
France	7c	1166	4·0	5·5
		2367	10·3	8·1
		3500	26·2	14·7
Russia	4-pr. (light)	1166	4·2	4·4
		2367	16·5	9·3
		3500	67·9	20·8
	4-pr. (heavy)	1166	2·6	1·7
		2367	6·7	7·3
		3500	11·5	13·4
	9-pr.	1166	3·1	2·6
		2367	12·8	7·2
		3500	4·0	14·9
Switzerland	8c	1166	1·9	2·2
		2367	7·9	6·7
		3500	23·9	12·9
	10c	1166	1·9	2·0
		2367	7·9	5·9
		3500	23·9	10·9

From the above tables one sees that the armaments of the field artilleries of the different powers are practically similar, both as regards the calibre and power of the guns.

In each country we generally find two different calibres—the lighter varying between 2·9 and 3·4 ins., and the heavier with a mean calibre of 4 ins. England possesses a third gun of 4 ins. calibre, and Russia another of 4·2 ins. Switzerland also has a third gun, called a "gun of position," which does not figure in these tables, because it can only be occasionally employed; it is an enormous piece which has been converted from a muzzle-loader to a breech-loader. They also talk in France of adopting a third gun of position of 5 ins. calibre.

It is quite certain that if one calibre only could be obtained to contend adequately against any obstacle on the battle-field, it would be an immense advantage, as it would ensure perfect uniformity and simplicity of *matériel*, greatly to the good of the service.

For this reason it is evident that it is much better to have two

different calibres than three. Anyhow, it appears to us that the extra trouble and complications which would arise from having a third calibre could never be compensated by the advantages it would give; unless the theatre of war were exceptionally covered with obstacles of the class of solid masonry, &c., and then it would be advisable to enter on the campaign provided with a special gun to meet a case of that sort.

The same would be necessary if the enemy on the defensive were known to have entrenched himself behind solid field fortifications.

If we consider lightness—which has such an important influence on mobility—Italy stands in the front rank with her gun of 7·5^c, weighing 6 cwt.*

The lightness of the projectile is a natural consequence of the smallness of the calibre. (Query, is that an advantage?)

All the other states seem to have settled on 9 lbs. as the minimum weight for the projectile; but considering that the Italian projectile breaks up into 24 fragments of a mean weight each of $3\frac{1}{2}$ ozs., whilst the projectiles of the other powers break up into a much greater number, but with a mean weight each of $1\frac{3}{4}$ ozs. (which would in many cases be harmless), the advantage in this particular appears to be on the side of the Italian gun. On the other hand, with the same gun, the weight of the projectile could without great difficulty be increased to 9 lbs.

Italian Field Artillery.

The Italian field artillery consists of 10 regiments, each composed of 10 batteries. These are in each regiment numbered from 1 to 10, and form three brigades—the two first of three batteries each, and the third of four. The third battery of each brigade is at present armed with the 12^c gun, but will soon have the new gun of 8·7^c.

All batteries have a peace and a war establishment. On the former, each battery has 6 guns, 6 wagons, 1 forge, and 2 general service wagons; on the latter, 8 guns, 8 wagons, 1 forge, and 3 general service wagons—total 20 carriages. The batteries of 7·5^c on this establishment are provided with 1280 rounds, carried as follows:—In the gun limber 32 common shell, 12 shrapnel, and 2 case shot. The wagon limber is packed similar to the gun limber, and in the wagon body boxes are 48 common shell and 18 shrapnel. In addition to this, each gun-carriage carries 2 case shot; therefore each piece carries 160 rounds, of which 112 are common shell, 42 are shrapnel, and 6 case shot.

The 7·5^c batteries have a complement of 164 men and 109 horses (on war footing). The 12^c batteries on war footing carry 768 rounds, or 96 per gun—viz., 88 common and shrapnel shell, and 8 case shot.

The 7^c batteries are called light batteries, and the 12^c heavy. Each regiment contains 6 of the former, and 4 of the latter—that is, in the proportion of 3 : 2.

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* When this was written, the English 9-pr. gun of 6 cwt. was evidently not known of. The 9-pr. gun originally mentioned in the tables was that of 8 cwt., and I made the alteration and substituted the description of the 6-cwt. gun.—J. C. D.

France and Austria have an equal number of heavy and light batteries (1 : 1).

Russia has the same proportion (1 : 1), if we omit the guns of position; but taking them into account, the proportion of light to heavy guns is 2 : 3.

Germany and England adopt the proportion of 1 : 1·4.*

Proportion of Artillery in an Army.

We will now turn to another question—viz., the apportioning of the artillery in an army.

The military forces of Italy are divided into armies, each of which is subdivided into 3 army corps, which in their turn consist each of 2 divisions and a reserve (*truppe supplétive.*)

To each division is assigned 1 brigade of artillery of 3 batteries, and to the reserve 1 brigade of 3 or 4 batteries; or, to express it in another manner, 1 regiment of field artillery goes to 1 army corps.

Number of Men.

With regard to the number of men composing an army corps:—

The division contains 4 regiments of infantry, each of 3 battalions; and including the different arms of the service, we have—

	Men.
For the 2 brigades	10,272
2 squadrons of cavalry	321
3 batteries of artillery	556
Effective total of 1 division	11,149
" " 2 divisions	22,298

The reserve troops consist of—

1 regiment of *Bersaglieri* (4 battalions)	3,382
2 regiments of cavalry of 4 squadrons	1,364
4 batteries of artillery	763
Total of 1 army corps	27,807

and 10 batteries, or 80 guns; therefore, the proportion of guns is 2·8 to every 1000 men.

Let us compare this with the proportion in other countries—

	No. of guns per 1000 men.
France	3·5
Germany	3·4
Austria	3
Russia	4
And with the cavalry	4·5

We ought to add that all the principal powers have a considerable number of horse artillery batteries, of which doubtless much is expected, and Italy does not possess any.

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* This refers to England's home army only, and does not include depôt batteries.

LIMBERS AND WAGONS.

BY

MAJOR W. B. E. ELLIS, R.A.

In "Proceedings, R.A. Institution," No. 8, Vol. IX., there was a brief comparison drawn by an officer of the Royal Carriage Department between three service limbers with two horses each, and one ammunition wagon with six horses.

The general results of the examination of this question were adverse to the three limbers.

In 1875, however, a proposal had been put forward by the writer to substitute two limbers for each wagon; these two limbers carrying between them the same amount of ammunition as the present service wagon.

Practical effect was given to this proposal early in 1876, so far that a service limber was temporarily converted on this plan, and put through a series of experiments. With the assistance of the various data given in the above two cases, the following facts may be considered established.

"The weight upon the shaft horse, in the wagon 60 lbs., becomes in the limber without a hind-carriage 96 lbs., which weight each of three out of six horses instead of but one would be oppressed by." This with three limbers; but in the writer's altered limber the weight on the shaft horse, even when that limber was not limbered-up, but by itself, without a hind-carriage, was found to be only 64 lbs. The difference between this and the 60 lbs. above quoted is so small that it may be put down as probably due to variation in the testing of the weight on the shafts, which requires great nicety of adjustment.

Now, with regard to the load and the motive power, the service wagon packed weighs 40 cwt. 0 qrs. 2 lbs., while the writer's limber, also packed, weighs 18 cwt. at most, or 2 cwt. 0 qrs. 24 lbs. more than the service limber, but 22 cwt. 0 qrs. 2 lbs. less than the ammunition wagon. Two of the proposed limbers would thus weigh 36 cwt. only, or 4 cwt. 0 qrs. 2 lbs. less than the service wagon, while carrying an equal number of rounds of ammunition, "which—the number of rounds of ammunition carried being the same in both cases—gives 4 cwt. 0 qrs. 2 lbs. of additional and perfectly useless load."

But in this comparison of the two limbers the extra weight is *with the wagon*, whereas in the case of the *three* service limbers the disadvantage rested with those limbers.

The wagon with six horses gives a load per horse of 747 lbs. One

of the proposed limbers could have four horses, while the other had only two horses, making together the six horses allowed for the wagon. With four horses in the writer's limber the load per horse would be 504 lbs., while with only two horses it would be 1008 lbs. (9 cwt.) This latter load, however, would be none too great for the second line of limbers, which need only move at a walk. The first line of limbers with four horses each could always keep up with the guns, even on service.

The number of carriages of a battery turned out on the proposed plan, with the same number of guns and carrying the same total number of rounds (888) as now, would be increased by four only; counting each separate limber as a carriage.

But such battery, on a peace footing, would require 12 less horses than are at present allotted to a battery in India. There would be one more spare wheel with each battery. The equipment itself would require exactly the same number of wheels to travel as at the present moment, and yet the extent of depth of the battery in column of route would be diminished by 2 yds.

It follows from the foregoing that, over and above any of the special advantages claimed by the writer for his plan, there would be a possibility of placing in the field without any extra expense in either horses, drivers, or harness, nine batteries for every eight batteries on the present system; or we may say 540 guns instead of 480 on a peace footing.

The special advantages claimed for this system are as follows:— Greatly increased mobility; eighteen more rounds with every gun limber than at present, and thorough interchangeability and uniformity of every part of the equipment; a more rapid and easy supply of ammunition in the field; much less weight on the shaft horse under the same conditions.

The alterations could be carried out quickly and at small cost, and the eventual economy would be very great.

The advantages possessed by a system of comparatively light limbers over a system of heavy ammunition wagons when marching over difficult country, and more especially in going down steep hills and in making sharp turns, are too obvious to require further comment.

MEMORANDUM.

In the course of the papers on "Principles of Gunnery" reference has been made to the Appendix. As this Appendix consists almost entirely of matter which has already appeared in the "Proceedings," it is not contemplated to republish it therein; it can, however, be obtained in a separate form on application to the Secretary.

PRINCIPLES OF GUNNERY.

RIFLED ORDNANCE.

BY

CAPTAIN J. SLADEN, R.A.

PROFESSOR OF ARTILLERY, R.M. ACADEMY, WOOLWICH.

(*Continued from p. 65.*)

CHAPTER V.

Resistance to the Motion of Projectiles in the Air.

Resistance of the Air.—Robins' Experiments.—Hutton's Experiments.—Hutton's Law.—Didion's Law.—Welter's Law.—Hélie's Law.—Bashforth's Experiments.—Report of Committee of Reference on Bashforth's Experiments.—Advantage of Bashforth's Method of Experimenting.—Object of the Experiments.—Bashforth's Conclusions.—Cubic Law retained for Convenience of Calculation.—Mayevski's Experiments.—Influence of the Form of the Projectile upon the Resistance.—Experiments to Determine the amount of Resistance of the Air to Different Forms of Heads of Projectiles.—Results of Experiments.—The Resistance of the Air to a Projectile in Motion.—The Retardation varies directly as the Resistance opposed to the Motion of the Projectile, and inversely as the Weight of the Projectile.—Equation of Motion connecting Distance and Velocity.—Approximate Calculation of Remaining Velocity with regard to Range.—The Value of the Coefficient K varies at Different Velocities.—Explanation and Use of the Table of Values of the Coefficient K.—Table connecting Distance and Velocity.—The Power which a Projectile in Motion has of maintaining its Velocity.—Equation of Motion connecting Time and Velocity.—Approximate Calculation of Remaining Velocity with regard to Time.—Distance and Velocity Table.—Time and Velocity Table.—Explanation of Tables I. and II.—Equation (I.), connecting Distance and Velocity.—Equation (II.), connecting Time and Velocity.—Examples in the Solution of Problems in Practical Gunnery by means of Tables I. and II.

Resistance of the air.

The resistance of the air to projectiles moving in it with high velocities has long been known to be very considerable, and many attempts have been made to find a *law* which would account for the results observed in practical gunnery.

Robins' experiments.

Robins' experiments in 1742 are the first recorded attempts to obtain the law of the resistance of the air to projectiles moving with high velocities. He fired spherical leaden bullets from a small-arm, and by means of the ballistic pendulum deduced the following general statements:—(1), that till the velocity of the projectile exceeds 1100 f.s., the resistance of the air may be taken to be as the *square of the velocity;* (2), that at the velocity of 1100 f.s. (nearly the same as that with which sound is propagated through the air), this law of the resistance is *altered;* (3), that if the velocity exceeds 1100 f.s., then the absolute quantity of that resistance in these greater velocities will be nearly

three times as great as it should be by a comparison with the lower velocities.*

Hutton's experiments.

Hutton afterwards (1790) made experiments with guns firing large spherical iron projectiles, and an improved ballistic pendulum, and came to the conclusion—(1), that the law of the resistance of the air was in a *higher ratio* than the *square of the velocity*, even at very low velocities; (2), that this ratio gradually increased with velocities up to 1600 f.s., where it is at the greatest, amounting in that maximum state to $2\frac{1}{10}$ times (instead of 3 times, as Robins asserted,) the quantity resulting from the ratio of the square of the velocity; (3) that for velocities greater than 1600 f.s. this ratio gradually *decreased.*

Hutton's law.

Hutton's law of the resistance of the air, deduced from his experiments, consisted of two terms—one varying as the velocity, the other as the square of the velocity; *i.e.*, if R denote the resistance of the air, and v the velocity of the projectile,

$$R \propto av + bv^2;$$

where a and b are constants determined experimentally.

Didion's law.

General Didion, of the French army, proposed another law of resistance, which, from experiments carried on at Metz in 1840, he considered to be nearer the truth. Didion's law of resistance also consisted of two terms—one varying as the square, the other as the cube of the velocity, or

$$R \propto \cdot 027\ (v^2 + \cdot 0023v^3).\dagger$$

Welter's law.

This formula not having proved entirely satisfactory, experiments were again carried on at Metz, in 1857, by Captain Welter, Professor at the School of Practical Artillery and Engineering, but this time with improved ballistic instruments. The old ballistic pendulum was discarded, and the velocities of spherical projectiles were taken by means of an *electro-ballistic* pendulum.‡ Captain Welter came to the conclusion that the resistance of the air to *spherical* projectiles moving at high velocities was simply proportional to the *cube of the velocity;*

$$\text{or } R \propto v^3.$$

Hélie's law.

Further experiments were carried on in 1860–1 at Gâvre with ogival-headed *elongated* projectiles, under the direction of M. Hélie (Professor in the French School of Naval Gunnery), from which he came to the conclusion, in his work "Traité de Balistique Experimentale," published in 1865, that the results of these experiments "authorised him to consider that the resistance of the air was proportional to the cube of the velocity, at least as long as the axis of the projectile did not deviate much from the tangent to the trajectory

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* *Vide* Robins' "Tracts on Gunnery," by Hutton, p. 181.

† *Vide* "Traité de Balistique Experimentale," par Helié, p. 168.

‡ An electro-ballistic pendulum is an instrument by which the exact instant of the passage of a projectile through a screen is registered by *electricity*, and the time of passing from one screen to another by means of a pendulum falling freely. These instruments have since been superseded by the more accurate instruments of Le Boulengé, Bashforth, and Watkin.

described by its centre of gravity;"* but it was not until Professor Bashforth carried out a series of systematic experiments with spherical and ogival-headed projectiles by means of his Clock Chronograph (1865 to 1870) that any *accurate* knowledge of the subject was obtained. A Committee of Reference appointed by the War Office, consisting of the Astronomer Royal, Professor Adams (Cambridge Observatory), Professor Stokes, of Cambridge, and Captain Andrew Noble, F.R.S., of Elswick, reported thus on these experiments:—

Bashforth's experiments.

"The results showed that for moderate variations of velocity the resistance may be taken to vary as the *cube of the velocity*; yet for considerable variations of velocity this law no longer holds good; and that if for convenience the resistance be still represented by an expression of the form cv^3, the coefficient c must be taken to vary continuously with the velocity. The experiments showed the values of the coefficient c of resistance corresponding to values of the velocity ranging from 850 to 1600 ft. per second. The coefficient is found to attain a maximum value for a velocity of about 1200 f.s. Professor Hélie's value of the coefficient of resistance is found to be true only for velocities in the neighbourhood of 950 f.s. The (cubic) law was stated by Professor Hélie in his work published in 1865, and it appears to have been in use for some years before that time in the School of Artillery at Metz; but Professor Bashforth, without being aware of this, independently deduced the same law from his own experiments, so far at least as the law can be considered true—viz., *for a limited range of velocity*. Professor Bashforth, by his valuable experimental determination of the coefficient of resistance corresponding to different velocities, has furnished the data which are *absolutely necessary* in order to make the law applicable in practice."†

Report of Committee of Reference on Bashforth's experiments.

Bashforth's method of experimenting consisted in observing the time of the passage of the *same* projectile through a series of successive equal distances.‡ Previous experiments had measured only two intervals of time at each round, and in order to obtain the coefficient of resistance for different velocities, several rounds were fired with varying charges to get the required velocities; whereas Bashforth, by arranging 10 screens at intervals of 50 yds. apart, in *one round* determined the coefficient of resistance for a considerable variation of velocity—the velocity being gradually reduced in the distance of 450 yds. by the resistance of the air.

Advantage of Bashforth's method of experimenting.

The Committee of Reference reported with regard to this point that "there is a great advantage in being able to measure *several* consecutive intervals of time by the same instrument; since in this way each experiment supplies the means of testing the *accuracy* of the results, which are wholly wanting when only two intervals of time are measured, and that by two different instruments."

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* *Vide* "Traité de Balistique Experimentale," p. 415.

† *Vide* Report of the Committee of Reference (p. 160 of "Reports on Experiments made with the Bashforth Chronograph.")

‡ *Vide* Bashforth's "Motion of Projectiles," p. 29.

Object of the experiments.

The object of these experiments was to determine whether the resistance of the air varied as the *cube of the velocity* for all velocities between 900 f.s. and 1700 f.s., and whether it varied also as the *square of the diameter* of the projectile.

Bashforth's conclusions.

The results showed that the resistance of the air for the same velocity and the same *form* of projectile, whether spherical or elongated, varies exactly as the *square of the diameter* of the projectile; also that the resistance of the air varies as the *cube of the velocity only for velocities between 1100 f.s. and 1350 f.s.*

The cubic law is not nearly correct for velocities between 900 f.s. and 1100 f.s.: the resistance of the air between these velocities varies approximately as the *sixth* power of the velocity.

The cubic law, again, is not correct for velocities above 1350 f.s.: the resistance of the air above this velocity varies approximately as the *square* of the velocity.

Bashforth's conclusions are, then, that

between the velocities of 900 and 1100 f.s.... $R \propto v^6$, approximately,
" " 1100 and 1350 f.s.... $R \propto v^3$, "
above 1350 f.s. ..... $R \propto v^2$. "

Cubic law retained for convenience of calculation.

Since the cubic law of resistance offers the greatest simplicity of calculation, Bashforth retained it for convenience as the basis for the calculation of remaining velocities, and represented the resistance of the air by an expression of the form cv^3; where the coefficient c is *variable*, depending upon the *form* of the projectile and upon the *velocity* with which it moves.

Mayevski's experiments.

Experiments on the resistance of the air to elongated projectiles in motion were made at St. Petersburg in 1868 and 1869, under the superintendence of General Mayevski, by means of two Boulengé chronographs. Mayevski supplemented his experiments by using the coefficient of resistance deduced by Bashforth, and adopted a method of calculation* of the trajectory of a projectile on the suppositions (which he considered borne out by the experiments) that

between the velocities of 1670 and 1180 f.s.... $R \propto v^3$, approximately,
" " 1180 and 918 f.s.... $R \propto v^6$, "
below 918 f.s. ..... $R \propto v^2 + v^4$, "

The calculations on these suppositions are not so simple as those obtained by using Bashforth's method of formulating the results of his experiments.

Influence of the form of the projectile upon the resistance.

The resistance experienced by a projectile in motion through the air is influenced by its *form or shape*—more especially by the shape of its *fore* part, which meets the air, although the shape of its *hinder* part has some influence on the resistance. The form which would theoretically encounter the least resistance in passing through the air is given by Piobert, in his "Cours d'Artillerie," p. 15.

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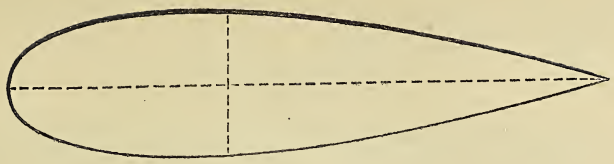
* *Vide* "Traité de Balistique Exterieure," par N. Mayevski. Paris, 1872.



Its length is five times its greatest diameter, and its largest section is placed at $\frac{2}{5}$ths of its length from the base.*

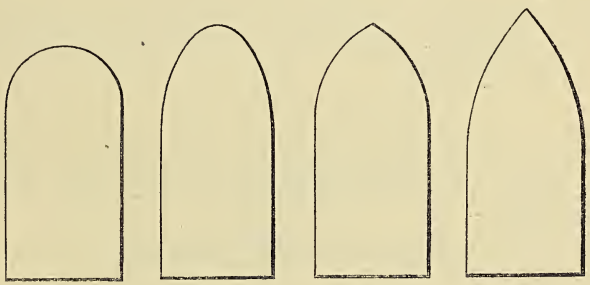
With service projectiles the base is generally flat, but slightly rounded at the edges for convenience in loading.

The total resistance to a projectile moving through the air is due (1) to the fore part of the projectile forcing its way through, and so displacing the particles of the air which impede its motion; (2) to the hinder part being dragged back by suction, owing to a formation of a partial vacuum in its rear.

Experiments to determine the amount of resistance of the air to different forms of heads of projectiles.

Experiments were made by Professor Bashforth with the Clock Chronograph to ascertain the amount of the resistance of the air to different forms of heads of projectiles, the form of the hinder part being flat in all.

Four different forms of head were experimented on—viz., (1) hemispherical head, (2) hemispheroidal head, (3) ogival head of 1 diameter, and (4) ogival head of 2 diameters. The object of the experiment was to determine which of these forms offered the least resistance to the motion of the projectile.



1. 2. 3. 4.

Results of experiments.

The results obtained under similar conditions of velocity were as follows:—

Form of head.	Coefficient of resistance $K = (1000)^3 c \times \frac{v}{d^2}$.
Hemispherical	132·9
Hemispheroidal	104·3
Ogival-head (1 diam.)	109·7
Ogival-head (2 diams.)	104·2

The coefficient c is put into the form $K = (1000)^3 c \times \frac{w}{d^2}$ for conve-

* *Vide* Owen's "Modern Artillery," p. 215.

nience of calculation; d being the diameter of the projectile in inches, and w its weight in lbs.: so that

$$c = \frac{d^2}{w} \frac{K}{(1000)^3}.$$

It was concluded that the resistance of the air to the hemispherical head was the greatest, and to the ogival head of 2 diameters the least, of the forms experimented on.

The resistance of the air to the hemispheroidal and ogival heads differs so little that there is practically not much to choose between them. Professor Bashforth states that "the slight variations in the resistances to the three latter forms lead to the conclusion that the amount of resistance offered by the air to the motion of elongated projectiles is little affected by the more or less pointed apex, but depends chiefly upon the form of head near its junction with the cylindrical body of the projectile. In this neighbourhood the forms of the hemispheroidal head and the ogival head struck with a radius of 2 diameters are the same, and the resistances are little different."

The resistance of the air to a projectile in motion.

THE RESISTANCE WHICH AN ELONGATED PROJECTILE IN MOTION MEETS WITH IN PASSING THROUGH THE AIR DEPENDS

(1) On the velocity of the projectile.
(2) On its sectional area.
(3) On the form of head.

For velocities between 1100 f.s. and 1350 f.s. the resistance varies as the *cube of the velocity*; so that if v = the velocity of projectile, d = its diameter, K' a coefficient depending on the form of head, the resistance opposed to its motion,

$$\text{or } R, \text{ varies as } v^3 d^2 K'.$$

The retardation varies directly as the resistance opposed to the motion of the projectile, and inversely as the weight of the projectile.

For projectiles with similar forms of heads K' is constant; so that within the limits of velocity mentioned above, and with ordinary service projectiles,

$$R \propto K' d^2 v^3 = \frac{K' d^2 v^3}{g}, \text{ suppose.}$$

The retardation, or the rate of loss of velocity, of the projectile owing to this resistance, varies *inversely as the weight of the projectile*; so that if w be the weight of the projectile, it follows that

$$\text{the retardation} = \frac{gR}{w} = K' v^3 \frac{d^2}{w}.$$

For convenience of calculation, suppose $K' = \frac{K}{(1000)^3}$; then the above relations become

$$\text{resistance } (R) = K \cdot \frac{d^2}{g} \cdot \left(\frac{v}{1000}\right)^3, \quad \ldots\ldots(1)$$

Equation of motion connecting distance and velocity.

$$\text{and retardation} = K \frac{d^2}{w} \left(\frac{v}{1000}\right)^3, \quad \ldots\ldots(2)$$

$$\text{or } v \frac{dv}{ds} = -\frac{d^2}{w} \frac{K v^3}{(1000)^3},$$

supposing the projectile to move in a straight line, unaffected by gravity;

$$\text{then } \frac{ds}{dv} = -\frac{(1000)^3}{Kv^2} \cdot \frac{w}{d^2},$$

$$\text{or } s = \frac{w}{d^2}\int \frac{(1000)^3 dv}{Kv^2}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

the limits of this integral being the velocities at the beginning and end of the distance, s.

Approximate calculation of remaining velocity with regard to range.

For velocities between 1100 f.s. and 1350 f.s., where the cubic law holds, the coefficient K may be given a constant value for the same form of projectile. Between these velocities for service ogival-headed projectiles

$$K = 108{\cdot}5.$$

When K is constant, equation (3) becomes

$$s = \frac{w}{d^2}\frac{(1000)^3}{K}\int \frac{dv}{v^2},$$

which may be integrated thus:

$$\frac{K}{(1000)^3}\frac{d^2}{w}s = \frac{1}{v} - \frac{1}{V},$$

$$\text{or } \frac{d^2}{w}s = \left(\frac{1}{v} - \frac{1}{V}\right)\frac{(1000)^3}{K}; \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where V is the muzzle velocity, and v the remaining velocity, at a given distance, s, from the muzzle.

Or, transposing,

$$v = \frac{V}{1 + \frac{K}{(1000)^3}\frac{d^2}{w}Vs}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

which gives the remaining velocity at a given distance, s, from the muzzle.

For velocities where the cubic law holds, and the projectile moves approximately in a straight line, the remaining velocity at a given *distance* may be fairly accurately determined by this formula by substituting the mean value of K given above.

For example: suppose it were required to find the remaining velocity of the 10-in. M.L. gun of 18 tons at 1000 ft.*

$$V = 1364 \text{ f.s.}, \quad \frac{d^2}{w} = {\cdot}24, \quad K = 108{\cdot}5, \text{ and } s = 1000.$$

These values substituted in equation (5) will give (v) the remaining velocity at 1000 ft.

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* *Vide* Table, "Comparison of M.L. Guns," p. 20.

$$\text{Thus } v = \frac{1364}{1 + \frac{108{\cdot}5}{(1000)^3} \times {\cdot}24 \times 1364 \times 1000}$$

$$= 1317 \text{ f.s.}$$

By the use of Bashforth's Distance and Velocity Table (*vide* p. 250) calculations of this kind are much simplified.

The value of the coefficient K varies at different velocities.

The value of K, however, cannot be taken as constant for large variations in velocity; so that it becomes necessary to tabulate the value of K for all practical velocities.

Up to the present time the value of this coefficient has been accurately determined for velocities varying from 1700 f.s. to 900 f.s. for ogival-headed projectiles. Experiments are now in contemplation to determine it for the lower velocities used in curved or indirect fire.

*Table showing the Values of K corresponding to Velocities at Intervals of 10 ft. per second. Elongated shot, ogival head.**

Velocity.	Value of K.	Velocity.	Value of K.	Velocity.	Value of K.	Velocity.	Value of K.
f.s.		f.s.		f.s.		f.s.	
900	64·4	1110	106·6	1310	107·7	1510	96·4
910	64·8	1120	107·1	1320	107·4	1520	95·5
920	65·3	1130	107·5	1330	107·1	1530	94·7
930	65·9	1140	107·9	1340	106·8	1540	93·8
940	66·6	1150	108·2	1350	106·4	1550	93·0
950	67·4	1160	108·5	1360	106·0	1560	92·2
960	68·4	1170	108·7	1370	105·6	1570	91·4
970	69·6	1180	108·9	1380	105·1	1580	90·6
980	71·0	1190	108·9	1390	104·6	1590	89·8
990	72·8	1200	108·9	1400	104·0	1600	89·0
1000	75·0	1210	108·9	1410	103·4	1610	88·2
1010	77·5	1220	108·9	1420	102·8	1620	87·4
1020	80·4	1230	108·8	1430	102·2	1630	86·7
1030	83·9	1240	108·8	1440	101·6	1640	86·0
1040	88·2	1250	108·7	1450	100·9	1650	85·4
1050	92·8	1260	108·6	1460	100·2	1660	85·0
1060	97·2	1270	108·5	1470	99·4	1670	84·6
1070	100·8	1280	108·3	1480	98·7	1680	84·3
1080	103·4	1290	108·1	1490	97·9	1690	84·1
1090	105·1	1300	107·9	1500	97·2	1700	83·9
1100	106·0						

N.B.—In the above table a cubic foot of dry air is supposed to weigh 530·6 grs., which corresponds to the barometer at 30·0 ins. and thermometer at 65·5° F. The value of K varies as the density of the air, but it is calculated at a standard density on the above supposition.

Explanation and use of the Table of Values of the Coefficient K.

Suppose the value of the coefficient K be required for a velocity of 1600 f.s.: opposite to 1600 in the velocity column, $K = 89{\cdot}0$.

EXAMPLE.—What is the resistance of the air in lbs. to an ogival-headed projectile of 16 ins. in diameter, moving with a velocity of 1600 f.s.?

From equation (1),

$$R = K\frac{d^2}{g} \cdot \left(\frac{v}{1000}\right)^3 = \frac{89 \times (16)^2}{32{\cdot}19}\left(\frac{1600}{1000}\right)^3 = 2899 \text{ lbs.}$$

* *Vide* p. 152, "Report on Experiments made with the Bashforth Chronograph to determine the Resistance of the Air to the Motion of Projectiles."

By substituting the mean value of K in the above table corresponding to the mean velocity $\frac{V+v}{2}$ in equation (5), the remaining velocity, v, may be approximated to; but in order to get accurate results it would be necessary to change the value of K continually, to correspond to the continual change of velocity owing to the resistance of the air, which would be a laborious calculation.

Table connecting distance and velocity.

In order to obviate this, Mr. Bashforth has tabulated the values of $\frac{d^2}{w}s = \left(\frac{1}{v} - \frac{1}{V}\right)\frac{(1000)^3}{K}$ for all values of K corresponding to velocities from 1700 f.s. to 500 f.s. In the absence of exact experiments for velocities below 900 f.s., it has been assumed that the coefficient K remains constant and equal to its value at 900 f.s., and that the cubic law holds good below 900 f.s. (*Vide* Table I., Distance and Velocity, p. 250.)

The power which a projectile in motion has of maintaining its velocity.

It has been stated that the rate at which a projectile loses velocity owing to the resistance of the air equals

$$K\frac{d^2}{w}\cdot\left(\frac{v}{1000}\right)^3;$$

[*vide* equation (2)]; but as K is a coefficient depending only on the form and velocity of the projectile, it follows for similarly shaped projectiles fired from guns of *different calibres* and moving with the same alterations of velocity, that

$$\text{the rate of loss of velocity varies simply as } \frac{d^2}{w};$$

or, inverting and putting it into other words,

$$\text{the power which a projectile has of } \textit{maintaining its velocity}$$

$$\text{varies as } \frac{w}{d^2} \text{ or } \frac{\text{weight of projectile}}{\text{square of its diameter}};$$

or the power of a projectile to maintain its velocity varies *directly as its weight, and inversely as the square of its diameter.*

With similarly shaped elongated projectiles the weight varies nearly as d^2l, where l is the length of the projectile; consequently

$$\text{power of the projectile} \propto \frac{w}{d^2} \propto \frac{d^2l}{d^2} \propto l;$$

or the power of the projectile varies as its length.

Thus the longer the projectile (*cæteris paribus*) the harder will it hit at any given range, and the greater will be its absolute range for any given muzzle velocity; but practical considerations limit the length of a projectile to about 3 calibres.

If elongated projectiles of similar shape were made the *same length in calibres*, it follows from what has been stated above that

$$\text{the power of the projectile varies as the calibre of the gun.}$$

Equation of motion connecting time and velocity.

IT NOW BECOMES NECESSARY TO INVESTIGATE THE CONDITIONS OF VELOCITY WITH RESPECT TO *time*.

From equation (2),

$$\text{retardation} = \frac{dv}{dt} = -\frac{d^2}{w} \cdot \frac{Kv^3}{(1000)^3},$$

supposing the projectile to move in a straight line unaffected by gravity; or, inverting and integrating,

$$t = \frac{w}{d^2} \int \frac{(1000)^3 dv}{Kv^3}; \quad \ldots\ldots\ldots\

The units employed are distance in feet, time in seconds, and velocity in feet seconds.

Explanation of Tables I. and II.

In Tables I. and II. the left hand vertical column (v) denotes velocities from 500 f.s. to 1700 f.s., at intervals of 10 f.s., and by means of the top horizontal column these velocities are subdivided into intervals of 1 f.s.

The figures in the vertical columns under 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 (Table I.), express the *distance in feet* corresponding to the velocities, and may be denoted by the abbreviation S_v.

Similarly, the figures in the vertical columns under 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 (Table II.), express the *time in seconds* corresponding to the velocities, and may be denoted by the abbreviation T_v.

For example: in Table I., suppose it required to find the distance corresponding to the velocity 601 f.s.—*i.e.*, $S_v = S_{601} = 14384{\cdot}8$ ft.; or, conversely, if $S_v = 14384{\cdot}8$ ft., $v = 601$ f.s.

Also, in Table II., suppose it required to find the time corresponding to the velocity 705 f.s.—*i.e.*, $T_v = T_{705} = 11{\cdot}0732$ secs.; or, conversely, if $T_v = 11{\cdot}0732$ secs., $v = 705$ f.s.

Equation (I.), connecting distance and velocity.

Table I. is obtained by calculating the integral in the left-hand member of the equation

$$\frac{d^2}{w} S = \int \frac{(1000)^3 dv}{Kv^2};$$

and when the integral is taken between the limits of velocity v and V, it may be expressed in the notation adopted in Table I. thus:

$$\frac{d^2}{w} S = \int_v^V \frac{(1000)^3 dv}{Kv^2} = S_v - S_V. \quad \text{.....(I.)}$$

Equation (II.), connecting time and velocity.

In the same way, Table II. is obtained by calculating the integral in the right-hand member of the equation

$$\frac{d^2}{w} T = \int \frac{(1000)^3 dv}{Kv^3};$$

and when the integral is taken between the limits of velocity v and V, it may be expressed in the notation adopted in Table II. thus:

$$\frac{d^2}{w} T = \int_v^V \frac{(1000)^3 dv}{Kv^3} = T_v - T_V. \quad \text{.....(II.)}$$

In order to make use of Tables I. and II. in the solution of problems in practical gunnery, it must be remembered that they apply *rigidly* only to elongated projectiles with ogival-shaped heads, and under conditions of atmosphere mentioned in the note on the Table of Values of K, and that

V = the velocity of the projectile at the beginning of the distance or time under consideration,
v = the velocity at the end of the distance or time under consideration,
S = the distance or range in *feet*,
T = the time in *seconds*,
d = diameter of projectile in *inches*,
w = weight of projectile in *lbs.*

Examples in the solution of problems in practical gunnery by means of Tables I. and II.

EXAMPLE (1).—In what range would the velocity of a projectile fired from the 9-in. M.L. gun be reduced from 1420 f.s. to 1240 f.s.?

For the 9-in. shell, $d = 8{\cdot}92$ ins., $w = 250$ lbs.; also $V = 1420$, $v = 1240$. Substituting in equation (I.),

$$\frac{d^2}{w} S = S_v - S_V;$$

$$\text{or } \frac{(8{\cdot}92)^2}{250} S = S_{1240} - S_{1420} = 2208{\cdot}6 - 1251{\cdot}1, \text{ by Table I.};$$

$$\text{or } {\cdot}3183S = 957{\cdot}5 \text{ ft.};$$

$$\text{so that } S = 3000 \text{ ft. nearly.}$$

i.e., the velocity would be reduced from 1420 f.s. to 1240 f.s. in about 3000 ft.

EXAMPLE (2).—In what *time* would the velocity of the same projectile be reduced from 1420 f.s. to 1240 f.s.?

Substituting in equation (II.),

$$\frac{d^2}{w} T = T_v - T_V;$$

$$\text{or } \frac{(8{\cdot}92)^2}{250} T = T_{1240} - T_{1420} = 1{\cdot}5285 - {\cdot}8057;$$

$$\text{or } {\cdot}3183T = {\cdot}7228 \text{ sec.};$$

$$\text{so that } T = 2{\cdot}27 \text{ secs.}$$

i.e., the velocity would be reduced from 1420 f.s. to 1240 f.s. in about 2·27 secs.

EXAMPLE (3).—Find the remaining velocity of the 12·5-in. M.L. gun at 3000 ft.

In this case, $w = 800$ lbs., $d = 12{\cdot}42$ ins., muzzle velocity $(V) = 1420$ f.s., $S = 3000$ ft.

Substituting in equation (I.),

$$\frac{d^2}{w} S = S_v - S_V;$$

$$\text{or } \frac{(12{\cdot}42)^2}{800} \times 3000 = S_v - S_{1420}.$$

Transposing,

$$S_v = \frac{(12{\cdot}42)^2}{8} \times 30 + S_{1420}$$

$$= 578{\cdot}4 + 1251{\cdot}1 \text{ (since } S_{1420} = 1251{\cdot}1 \text{ by Table I.)};$$

$$\text{or } S_v = 1829{\cdot}5 \text{ ft.};$$

then from Table I. $v = 1306{\cdot}6$ f.s.

i.e., the remaining velocity at the distance of 3000 ft. from the muzzle is 1306·6 f.s.

EXAMPLE (4).—A shell fired from the 64-pr. M.L. gun with a charge of 10 lbs. of powder was observed to strike the crest of a parapet in 3 secs.; the muzzle velocity is known to be 1383 f.s. Find the striking velocity and the range.

In this case, $w = 64$ lbs., $d = 6{\cdot}22$ ins., $V = 1383$ f.s., $T = 3$ secs.

Substituting in equation (II.),

$$\frac{d^2}{w} T = T_v - T_V;$$

$$\text{or } \frac{(6{\cdot}22)^2}{64} \times 3 = T_v - T_{1383};$$

$$\text{or } T_v = 1{\cdot}814 + {\cdot}9351 \text{ (since } T_{1383} = {\cdot}9351 \text{ sec. by Table II.)};$$

$$= 2{\cdot}7491 \text{ secs.};$$

then from Table II. $v = 1049$ f.s.

i.e., the striking velocity at the end of 3 secs. from firing = 1049 f.s.

Next, to find the range:—

Substituting in equation (I.),

$$\frac{d^2}{w} S = S_v - S_V;$$

$$\text{or } \frac{(6{\cdot}22)^2}{64} S = S_{1049} - S_{1383};$$

$$\text{or } {\cdot}6045S = 3595{\cdot}6 - 1432{\cdot}4;$$

$$\text{or } S = \frac{2163{\cdot}2}{{\cdot}6045} = 3578 \text{ ft.}$$

i.e., the distance of the crest of the parapet from the gun is 3578 ft.

Table showing the Resistance of the Air in lbs. to Elongated Projectiles with Ogival Heads, from 1 in. to 15 ins. in diameter, at velocities of from 900 f.s. to 1700 f.s.

Velocity.	Diameter of projectile.															Velocity.
	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.	12 in.	13 in.	14 in.	15 in.	
f.s.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	f.s.
900	1·4584	5·8	13·1	23·3	36·5	52·5	71·5	93·3	118	146	176	210	246	286	328	900
950	1·7951	7·2	16·2	28·7	44·9	64·6	88	115	145	180	217	258	303	352	404	950
1000	2·3299	9·3	21	37·3	58·2	83·9	114	149	189	233	282	336	394	457	524	1000
1050	3·3373	13·3	30	53·4	83·4	120	164	214	270	334	404	481	564	654	751	1050
1100	4·3829	17·5	39	70	110	158	215	281	355	438	530	631	741	859	986	1100
1150	5·1121	20·4	46	82	128	184	250	327	414	511	619	736	864	1002	1150	1150
1200	5·8457	23·4	53	94	146	210	286	374	474	585	707	842	988	1146	1315	1200
1250	6·5952	26·4	59	106	165	237	323	422	534	660	798	950	1115	1293	1484	1250
1300	7·3641	29·5	66	118	184	265	361	471	596	736	891	1060	1245	1443	1657	1300
1350	8·1322	32·5	73	130	203	293	398	520	659	813	984	1171	1374	1594	1830	1350
1400	8·8650	35·5	80	142	222	319	434	567	718	887	1073	1277	1498	1738	1995	1400
1450	9·5556	38·2	86	153	239	344	468	612	774	956	1156	1376	1615	1873	2150	1450
1500	10·1902	40·8	92	163	255	367	499	652	825	1019	1233	1467	1722	1997	2293	1500
1550	10·7585	43	97	172	269	387	527	689	871	1076	1302	1549	1818	2109	2421	1550
1600	11·3245	45·3	102	181	283	408	555	725	917	1132	1370	1631	1914	2220	2548	1600
1650	11·9174	47·7	107	191	298	429	584	763	965	1192	1442	1716	2014	2336	2681	1650
1700	12·8050	51·2	115	205	320	461	627	820	1037	1281	1549	1844	2164	2510	2881	1700

NOTE.—The values of K for spherical shot have also been determined experimentally for velocities varying from 850 to 2150 f.s. Also tables of S_v and T_v have been calculated for spherical shot. (*Vide* "Proceedings, R.A. Institution," Vols. VII. and VIII.)

TABLE I.

Distance and Velocity Table. $\frac{d^2}{w} S = S_v - S_V$.

*v.	0	1	2	3	4	5	6	7	8	9
f.s.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
50	19604·0	19542·0	19480·2	19418·6	19357·2	19296·1	19235·2	19174·6	19114·3	19054·3
51	18994·6	18935·1	18875·8	18816·7	18757·8	18699·1	18640·7	18582·6	18524·6	18466·8
52	18409·2	18351·9	18294·9	18238·0	18181·3	18124·8	18068·5	18012·5	17956·7	17901·1
53	17845·7	17790·6	17735·6	17680·8	17626·2	17571·9	17517·8	17463·9	17410·1	17356·5
54	17303·2	17250·1	17197·2	17144·4	17091·8	17039·4	16987·1	16935·0	16883·1	16831·5
55	16780·2	16729·1	16678·1	16627·2	16576·5	16526·0	16475·7	16425·6	16375·6	16325·8
56	16276·2	16226·9	16177·7	16128·6	16079·6	16030·8	15982·2	15933·8	15885·6	15837·6
57	15789·8	15742·1	15694·6	15647·2	15600·0	15552·9	15506·0	15459·3	15412·7	15366·3
58	15320·1	15274·0	15228·1	15182·3	15136·7	15091·2	15045·9	15000·7	14955·7	14910·9
59	14866·2	14821·7	14777·3	14733·1	14689·0	14645·1	14601·3	14557·7	14514·2	14470·8
60	14427·7	14384·8	14341·9	14299·1	14256·4	14213·8	14171·3	14129·0	14086·9	14045·0
61	14003·3	13961·7	13920·2	13878·9	13837·6	13796·4	13755·3	13714·4	13673·7	13633·2
62	13592·8	13552·4	13512·2	13472·1	13432·2	13392·4	13352·7	13313·1	13273·7	13234·4
63	13195·2	13156·1	13117·3	13078·5	13039·8	13001·2	12962·8	12924·5	12886·3	12848·2
64	12810·2	12772·3	12734·6	12697·0	12695·5	12622·1	12584·8	12547·6	12510·6	12473·7
65	12436·9	12400·2	12363·7	12327·2	12290·8	12254·5	12218·3	12182·3	12146·4	12110·6
66	12074·9	12039·3	12003·9	11968·5	11933·2	11898·0	11863·0	11828·1	11793·2	11758·4
67	11723·7	11689·1	11654·7	11620·4	11586·2	11552·1	11518·1	11484·2	11450·4	11416·7
68	11383·0	11349·4	11316·0	11282·7	11249·5	11216·3	11183·3	11150·4	11117·5	11084·7
69	11052·0	11019·4	10987·0	10954·6	10922·3	10890·1	10857·9	10825·9	10794·0	10762·2
70	10730·5	10698·9	10667·4	10635·9	10604·5	10573·2	10542·0	10510·9	10479·9	10448·9
71	10418·0	10387·2	10356·5	10326·0	10295·5	10265·1	10234·8	10204·6	10174·4	10144·3
72	10114·3	10084·4	10054·6	10024·9	9995·2	9965·6	9936·1	9906·7	9877·4	9848·1
73	9818·9	9789·8	9760·8	9731·9	9703·0	9674·2	9645·5	9616 9	9588·3	9559·8
74	9531·4	9503·1	9474·9	9446·7	9418·6	9390·6	9362·6	9334·7	9306·9	9279·2
75	9251·6	9224·1	9196·6	9169·2	9141·8	9114·5	9087·3	9060·2	9033·1	9006·1
76	8979·2	8952·4	8925·7	8899·0	8872·3	8845·7	8819·2	8792·8	8766·4	8740·1
77	8713·9	8687·7	8661·6	8635·6	8609·7	8583·8	8558·0	8532·3	8506·0	8480·9
78	8455·3	8429·8	8404·4	8379·0	8353·7	8328·5	8303·3	8278·2	8253·2	8228·2
79	8203·3	8178·5	8153·7	8129·0	8104·3	8079·7	8055·2	8030·8	8006·4	7982·0
80	7957·7	7933·5	7909·3	7885·2	7861·1	7837·1	7813·2	7789·3	7765·5	7741·7
81	7718·0	7694·4	7670·8	7647·3	7623·8	7600·4	7577·0	7553·7	7530·5	7507·3
82	7484·2	7461·1	7438·1	7415·1	7392·2	7369·4	7346·6	7323·9	7301·2	7278·6
83	7256·0	7233·5	7211·1	7188·7	7166·3	7144·0	7121·8	7099·6	7077·5	7055·4
84	7033·4	7011·4	6989·5	6967·6	6945·8	6924·0	6902·2	6880·5	6858·9	6837·3
85	6815·8	6794·4	6773·0	6751·6	6730·3	6709·0	6687·8	6666·6	6645·5	6624·5
86	6603·5	6582·5	6561·6	6540·7	6519·9	6499·1	6478·4	6457·7	6437·1	6416·5
87	6395·9	6375·4	6355·0	6334·6	6314·2	6293·9	6273·7	6253·5	6233·3	6213·2
88	6193·1	6173·1	6153·1	6133·2	6113·3	6093·4	6073·6	6053·8	6034·1	6014·4
89	5994·8	5975·2	5955·7	5936·2	5916·7	5897·3	5877·9	5858·6	5839·3	5820·0
90	5800·8	5781·6	5762·5	5743·5	5724·5	5705·6	5686·7	5667·9	5649·2	5630·5
91	5611·8	5593·2	5574·7	5556·2	5537·7	5519·3	5500·9	5482·6	5464·4	5446·2
92	5428·1	5410·0	5392·0	5374·1	5356·2	5338·3	5320·5	5302·8	5285·1	5267·5
93	5249·9	5232·4	5215·0	5197·6	5180·2	5162·9	5145·7	5128·5	5111·4	5094·3
94	5077·3	5060·4	5043·5	5026·6	5009·8	4993·0	4976·3	4959·6	4943·0	4926·5
95	4910·0	4893·6	4877·3	4861·0	4844·7	4828·5	4812·4	4796·3	4780·3	4764·4
96	4748·5	4732·7	4716·9	4701·2	4685·5	4669·9	4654·4	4638·9	4623·5	4608·1
97	4592·8	4577·6	4562·4	4547·3	4532·2	4517·2	4502·3	4487·4	4472·6	4457·8
98	4443·1	4428·5	4413·9	4399·4	4384·9	4370·5	4356·2	4342·0	4327·8	4313·6
99	4299·5	4285·4	4271·4	4257·5	4243·7	4230·0	4216·4	4202·8	4189·3	4175·8
100	4162·4	4149·1	4135·9	4122·8	4109·7	4096·7	4083·8	4070·9	4058·1	4045·3
101	4032·6	4020·0	4007·5	3995·0	3982·5	3970·1	3957·8	3945·6	3933·5	3921·4
102	3909·5	3897·7	3886·0	3874·3	3862·7	3851·2	3839·8	3828·5	3817·3	3806·1
103	3795·0	3784·0	3773·0	3762·1	3751·2	3740·4	3729·6	3718·9	3708·3	3697·7
104	3687·2	3676·8	3666·4	3656·1	3645·8	3635·6	3625·5	3615·5	3605·5	3595·6
105	3585·8	3576·1	3566·5	3556·9	3547·3	3537·8	3528·4	3519·1	3509·8	3500·6
106	3491·4	3482·3	3473·2	3464·2	3455·2	3446·3	3437·5	3428·7	3419·9	3411·1

* In the left hand vertical column the figures are hundreds and tens; thus, 51 means five hundred and ten feet seconds. The unit figure of velocity is given in the top horizontal column; thus, if velocity (v) = 504 f.s., then $S_v = S_{504} = 19357{\cdot}2$ ft., or, conversely, if $S_v = 19357{\cdot}2$ ft., then $v = 504$ f.s.

TABLE I.—*(Continued).*

v.	0	1	2	3	4	5	6	7	8	9
f.s.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
107	3402·4	3393·8	3385·2	3376·7	3368·1	3359·6	3351·2	3342·8	3334·4	3326·0
108	3317·7	3309·5	3301·3	3293·1	3284·9	3276·7	3268·6	3260·5	3252·4	3244·3
109	3236·3	3228·4	3220·4	3212·5	3204·5	3196·6	3188·7	3180·9	3173·1	3165·3
110	3157·5	3149·7	3141·9	3134·2	3126·5	3118·7	3111·0	3103·3	3095·6	3087·9
111	3080·3	3072·8	3065·2	3057·6	3050·1	3042·5	3035·0	3027·5	3020 0	3012·6
112	3005·1	2997·7	2990·3	2982·9	2975·5	2968·1	2960·8	2953·4	2946·1	2938·7
113	2931·4	2924·1	2916·8	2909·6	2902·4	2895·2	2888·1	2880·9	2873·7	2866·6
114	2859·4	2852·3	2845·2	2838·1	2831·0	2823·9	2816·9	2809·8	2802·8	2795·8
115	2788·8	2781·8	2774·9	2767·9	2761·0	2754·0	2747·1	2740·2	2733·3	2726·5
116	2719·6	2712·8	2705·9	2699·1	2692·3	2685·5	2678·7	2672·0	2665·2	2658·5
117	2651·7	2645·0	2638·3	2631·6	2625·0	2618·3	2611·6	2605·0	2598·4	2591·8
118	2585·2	2578·6	2572·1	2565·5	2558·9	2552·4	2545·8	2539·3	2532·8	2526·3
119	2519·8	2513·4	2506·9	2500·4	2494·0	2487·5	2481·1	2474·7	2468·3	2461·9
120	2455·5	2449·1	2442·8	2436·4	2430·1	2423·8	2417·4	2411·1	2404·8	2398·5
121	2392·2	2386·0	2379·7	2373·5	2367·3	2361·0	2354·8	2348·6	2342·4	2336·2
122	2330·0	2323·9	2317·7	2311·6	2305·5	2299·3	2293·2	2287·1	2281·0	2274·9
123	2268·8	2262·7	2256·7	2250·7	2244·6	2238·6	2232·6	2226·6	2220·6	2214·6
124	2208·6	2202·6	2196·7	2190·7	2184·8	2178·8	2172·9	2166·9	2161·0	2155·1
125	2149·2	2143·3	2137·5	2131·6	2125·8	2119·9	2114·1	2108·2	2102·4	2096·6
126	2090·8	2085·0	2079·2	2073·4	2067·6	2061·9	2056·1	2050·4	2044·7	2038·9
127	2033·2	2027·5	2021·8	2016·1	2010·5	2004·8	1999·1	1993·5	1987·8	1982·2
128	1976·5	1970·8	1965·2	1959·6	1954·0	1948·4	1942·8	1937·2	1931·7	1926·1
129	1920·5	1915·0	1909·4	1903·9	1898·4	1892·8	1887·3	1881·8	1876·3	1870·8
130	1865·3	1859·8	1854·4	1848·9	1843·5	1838·0	1832·6	1827·2	1821·7	1816·3
131	1810·9	1805·5	1800·1	1794·7	1789·3	1783·9	1778·5	1773·1	1767·8	1762·4
132	1757·0	1751·7	1746·3	1741·0	1735·7	1730·4	1725·1	1719·8	1714·5	1709·2
133	1703·9	1698·6	1693·4	1688·1	1682·9	1677·6	1672·4	1667·1	1661·9	1656·7
134	1651·4	1646·2	1641·0	1635·8	1630·6	1625·4	1620·2	1615·0	1609·9	1604·7
135	1599·5	1594·4	1589·2	1584·1	1578·9	1573·8	1568·7	1563·5	1558·4	1553·3
136	1548·2	1543·1	1538·0	1533·0	1527·9	1522·8	1517·8	1512·7	1507·7	1502·6
137	1497·6	1492·5	1487·5	1482·5	1477·4	1472·4	1467·4	1462·3	1457·3	1452·3
138	1447·3	1442·3	1437·3	1432·4	1427·4	1422·4	1417·5	1412·5	1407·6	1402·6
139	1397·7	1392·7	1387·8	1382·9	1377·9	1373·0	1368·1	1363·1	1358·2	1353·3
140	1348·4	1343·5	1338·6	1333·7	1328·8	1323·9	1319·0	1314·1	1309·3	1304·4
141	1299·5	1294·7	1289·8	1284·9	1280·1	1275·2	1270·4	1265·6	1260·8	1255·9
142	1251·1	1246·3	1241·5	1236·6	1231·8	1227·0	1222·2	1217·4	1212·6	1207·8
143	1203·0	1198·2	1193·4	1188·7	1183·9	1179·1	1174·4	1169·6	1164·9	1160·2
144	1155·4	1150·7	1145·9	1141·2	1136·4	1131·7	1126·9	1122·2	1117·5	1112·7
145	1108·0	1103·3	1098·6	1093·9	1089·2	1084·5	1079·8	1075·1	1070·4	1065·8
146	1061·1	1056·4	1051·7	1047·1	1042·4	1037·7	1033·1	1028·4	1023·7	1019·1
147	1014·4	1009·8	1005·1	1000·5	995·8	991·2	986·6	981·9	977·3	972·7
148	968·0	963·4	958·8	954·1	949·5	944·9	940·3	935·7	931·1	926·5
149	921·9	917·3	912·7	908·1	903·5	898·9	894·3	889·7	885·1	880·6
150	876·0	871·4	866·9	862·3	857·8	853·2	848·6	844·1	839·5	835·0
151	830·4	825·9	821·3	816·8	812·2	807·7	803·2	798·6	794·1	789·5
152	785·0	780·5	775·9	771·4	766·9	762·3	757·8	753·3	748·7	744·2
153	739·7	735·2	730·7	726·2	721·7	717·2	712·7	708·2	703·7	699·2
154	694·7	690·2	685·7	681·2	676·8	672·3	667·8	663·3	658·8	654·4
155	649·9	645·4	640·9	636·5	632·0	627·5	623·1	618·6	614·2	609·7
156	605·3	600·8	596·4	591·9	587·5	583·0	578·6	574·1	569·7	565·2
157	560·8	556·4	551·9	547·5	543·0	538·6	534·2	529·7	525·3	520·9
158	516·4	512·0	507·6	503·1	498·7	494·3	489·9	485·5	481·1	476·7
159	472·3	467·9	463·5	459·1	454·7	450·3	445·9	441·5	437·1	432·7
160	428·3	423·9	419·5	415·1	410·7	406·4	402·0	397·6	393·2	388·9
161	384·5	380·1	375·8	371·4	367·1	362·7	358·3	354·0	349·6	345·3
162	340·9	336·5	332·2	327·8	323·5	319·1	314·8	310·4	306·1	301·7
163	297·4	293·1	288·7	284·4	280·0	275·7	271·4	267·0	262·7	258·4
164	254·0	249·7	245·4	241·0	236·7	232·4	228·1	223·8	219·5	215·2
165	210·9	206·6	202·3	198·0	193·7	189·4	185·1	180·8	176·5	172·3
166	168·0	163·7	159·5	155·2	150·9	146·7	142·4	138·2	134·0	129·7
167	125·5	121·3	117·0	112·8	108·6	104·3	100·1	95·9	91·7	87·5
168	83·3	79·1	74·9	70·7	66·5	62·3	58·1	53·9	49·8	45·6
169	41·4	37·2	33·1	28·9	24·8	20·7	16·5	12·3	8·2	4·1
170	0·0									

Table II.

Time and Velocity Table. $\frac{d^2}{w} T = T_v - T_V$.

*v.	0	1	2	3	4	5	6	7	8	9
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.
50	26·5083	26·3844	26·2612	26·1388	26·0172	25·8963	25·7762	25·6567	25·5379	25·4198
51	25·3024	25·1857	25·0697	24·9543	24·8396	24·7255	24·6121	24·4994	24·3873	24·2759
52	24·1652	24·0552	23·9457	23·8368	23·7285	23·6209	23·5139	23·4075	23·3017	23·1965
53	23·0919	22·9879	22·8845	22·7817	22·6795	22·5778	22·4766	22·3760	22·2760	22·1766
54	22·0778	21·9795	21·8817	21·7844	21·6877	21·5915	21·4958	21·4006	21·3060	21·2119
55	21·1184	21·0254	20·9328	20·8407	20·7491	20·6580	20·5674	20·4773	20·3877	20·2986
56	20·2100	20·1218	20·0341	19·9468	19·8600	19·7737	19·6879	19·6025	19·5175	19·4330
57	19·3489	19·2653	19·1821	19·0994	19·0171	18·9352	18·8537	18·7726	18·6920	18·6118
58	18·5320	18·4527	18·3738	18·2952	18·2170	18·1392	18·0619	17·9849	17·9083	17·8321
59	17·7563	17·6809	17·6059	17·5312	17·4569	17·3830	17·3094	17·2362	17·1634	17·0910
60	17·0190	16·9474	16·8761	16·8051	16·7344	17·6640	16·5940	16·5244	16·4551	16·3862
61	16·3176	16·2494	16·1815	16·1139	16·0466	15·9797	15·9131	15·8468	15·7809	15·7153
62	15·6500	15·5851	15·5204	15·4560	15·3919	15·3281	15·2646	15·2014	15·1386	15·0761
63	15·0139	14·9520	14·8903	14·8289	14·7678	14·7070	14·6465	14·5863	14·5264	14·4668
64	14·4074	14·3483	14·2895	14·2309	14·1726	14·1146	14·0569	13·9994	13·9422	13·8853
65	13·8286	13·7722	13·7160	13·6601	13·6045	13·5491	13·4940	13·4391	13·3845	13·3301
66	13·2759	13·2220	13·1684	13·1150	13·0618	13·0089	12·9562	12·9038	12·8516	12·7996
67	12·7479	12·6964	12·6451	12·5940	12·5432	12·4926	12·4422	12·3920	12·3421	12·2924
68	12·2429	12·1937	12·1447	12·0958	12·0471	11·9986	11·9504	11·9025	11·8547	11·8071
69	11·7597	11·7125	11·6655	11·6188	11·5723	11·5260	11·4799	11·4340	11·3882	11·3426
70	11·2972	11·2520	11·2070	11·1622	11·1176	11·0732	11·0290	10·9850	10·9412	10·8975
71	10·8540	10·8107	10·7675	10·7246	10·6819	10·6394	10·5970	10·5548	10·5127	10·4708
72	10·4291	10·3875	10·3461	10·3049	10·2639	10·2232	10·1826	10·1421	10·1018	10·0616
73	10·0216	9·9816	9·9420	9·9025	9·8632	9·8241	9·7851	9·7462	9·7075	9·6689
74	9·6305	9·5922	9·5541	9·5162	9·4784	9·4408	9·4034	9·3661	9·3289	9·2919
75	9·2550	9·2183	9·1817	9·1453	9·1090	9·0728	9·0368	9·0009	8·9652	8·9296
76	8·8941	8·8588	8·8236	8·7886	8·7537	8·7189	8·6843	8·6498	8·6155	8·5813
77	8·5472	8·5133	8·4795	8·4458	8·4122	8·3788	8·3455	8·3123	8·2793	8·2464
78	8·2136	8·1809	8·1484	8·1160	8·0837	8·0515	8·0195	7·9876	7·9558	7·9241
79	7·8926	7·8612	7·8299	7·7987	7·7676	7·7366	7·7058	7·6751	7·6445	7·6139
80	7·5835	7·5532	7·5231	7·4931	7·4631	7·4333	7·4036	7·3741	7·3446	7·3152
81	7·2859	7·2567	7·2276	7·1986	7·1698	7·1411	7·1125	7·0840	7·0556	7·0272
82	6·9990	6·9709	6·9429	6·9150	6·8871	6·8594	6·8318	6·8043	6·7769	6·7496
83	6·7224	6·6953	6·6683	6·6414	6·6146	6·5878	6·5612	6·5347	6·5083	6·4819
84	6·4557	6·4296	6·4036	6·3776	6·3517	6·3259	6·3002	6·2746	6·2491	6·2236
85	6·1983	6·1731	6·1480	6·1229	6·0979	6·0730	6·0482	6·0236	5·9990	5·9744
86	5·9499	5·9255	5·9012	5·8770	5·8529	5·8289	5·8049	5.7810	5·7572	5·7335
87	5·7099	5·6864	5·6629	5·6395	5·6162	5·5930	5·5699	5·5468	5·5238	5·5009
88	5·4781	5·4553	5·4326	5·4100	5·3875	5·3651	5·3428	5·3205	5·2983	5·2762
89	5·2541	5·2321	5·2102	5·1884	5·1666	5·1449	5·1233	5·1018	5·0803	5·0589
90	5·0375	5·0163	4·9952	4·9741	4·9531	4·9321	4·9112	4·8904	4·8697	4·8491
91	4·8286	4·8082	4·7878	4·7675	4·7473	4·7272	4·7072	4·6873	4·6674	4·6476
92	4·6279	4·6083	4·5888	4·5693	4·5499	4·5306	4·5114	4·4923	4·4732	4·4542
93	4·4353	4·4165	4·3978	4·3791	4·3605	4·3421	4·3236	4·3053	4·2870	4·2688
94	4·2506	4·2326	4·2147	4·1968	4·1790	4·1612	4·1436	4·1260	4·1085	4·0911
95	4·0738	4·0565	4·0393	4·0222	4·0052	3·9883	3·9714	3·9546	3·9379	3·9213
96	3·9047	3·8882	3·8718	3·8555	3·8393	3·8231	3·8070	3·7910	3·7751	3·7592
97	3·7434	3·7277	3·7121	3·6966	3·6811	3·6657	3·6504	3·6352	3·6200	3·6049
98	3·5899	3·5750	3·5602	3·5455	3·5308	3·5162	3·5017	3·4873	3·4729	3·4586
99	3·4444	3·4303	3·4163	3·4024	3·3885	3·3747	3·3610	3·3474	3·3339	3·3204
100	3·3070	3·2937	3·2805	3·2674	3·2544	3·2414	3·2285	3·2157	3·2030	3·1904
101	3·1778	3·1653	3·1529	3·1406	3·1284	3·1163	3·1042	3·0922	3·0803	3·0685
102	3·0567	3·0451	3·0335	3·0220	3·0106	2·9992	2·9879	2·9767	2·9656	2·9546
103	2·9436	2·9328	2·9220	2·9113	2·9007	2·8902	2·8798	2·8694	2·8591	2·8489
104	2·8388	2·8288	2·8188	2·8089	2·7991	2·7894	2·7798	2·7703	2·7608	2·7514
105	2·7420	2·7328	2·7236	2·7144	2·7053	2·6963	2·6874	2·6785	2·6697	2·6610
106	2·6523	2·6437	2·6351	2·6266	2·6182	2·6098	2·6015	2·5932	2·5850	2·5768

Vide note, Table I. EXAMPLE.—If $v = 504$ f.s., $T_v = T_{504} = 26{\cdot}0172$ secs.; or if $T_v = 26{\cdot}0172$ secs., $v = 504$ f.s.

TABLE II.—(*Continued.*)

v.	0	1	2	3	4	5	6	7	8	9
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.
107	2·5687	2·5606	2·5526	2·5446	2·5366	2·5287	2·5208	2·5130	2·5052	2·4975
108	2·4898	2·4821	2·4745	2·4669	2·4593	2·4518	2·4443	2·4369	2·4295	2·4221
109	2·4147	2·4074	2·4001	2·3928	2·3855	2·3783	2·3711	2·3640	2·3568	2·3497
110	2·3426	2·3355	2·3285	2·3214	2·3144	2·3074	2·3005	2·2936	2·2867	2·2798
111	2·2729	2·2661	2·2592	2·2524	2·2456	2·2388	2·2321	2·2254	2·2187	2·2120
112	2·2053	2·1987	2·1921	2·1855	2·1789	2·1723	2·1658	2·1593	2·1528	2·1464
113	2·1399	2·1335	2·1271	2·1207	2·1134	2·1079	2·1016	2·0953	2·0890	2·0827
114	2·0764	2·0702	2·0639	2·0577	2·0515	2·0453	2·0392	2·0330	2·0269	2·0208
115	2·0147	2·0087	2·0026	1·9966	1·9905	1·9845	1·9785	1·9726	1·9667	1·9607
116	1·9548	1·9489	1·9431	1·9372	1·9314	1·9255	1·9197	1·9139	1·9081	1·9024
117	1·8966	1·8909	1·8852	1·8795	1·8738	1·8681	1·8625	1·8568	1·8512	1·8455
118	1·8399	1·8343	1·8287	1·8232	1·8176	1·8121	1·8066	1·8011	1·7956	1·7901
119	1·7847	1·7792	1·7738	1·7684	1·7630	1·7576	1·7523	1·7469	1·7416	1·7362
120	1·7309	1·7256	1·7203	1·7150	1·7098	1·7045	1·6992	1·6940	1·6888	1·6836
121	1·6784	1·6732	1·6631	1·6629	1·6578	1·6526	1·6475	1·6424	1·6373	1·6323
122	1·6272	1·6222	1·6172	1·6121	1·6071	1·6021	1·5971	1·5922	1·5872	1·5823
123	1·5773	1·5724	1·5675	1·5626	1·5577	1·5528	1·5479	1·5431	1·5382	1·5334
124	1·5285	1·5237	1·5189	1·5141	1·5093	1·5045	1·4997	1·4950	1·4903	1·4855
125	1·4808	1·4761	1·4714	1·4667	1·4620	1·4574	1·4527	1·4481	1·4435	1·4388
126	1·4342	1·4296	1·4250	1·4204	1·4158	1·4113	1·4068	1·4022	1·3977	1·3932
127	1·3887	1·3842	1·3797	1·3752	1·3708	1·3663	1·3619	1·3574	1·3530	1·3486
128	1·3442	1·3398	1·3354	1·3310	1·3267	1·3223	1·3180	1·3137	1·3093	1·3050
129	1·3007	1·2964	1·2921	1·2878	1·2835	1·2792	1·2749	1·2707	1·2665	1·2622
130	1·2580	1·2538	1·2496	1·2454	1·2412	1·2370	1·2329	1·2287	1·2246	1·2204
131	1·2163	1·2122	1·2080	1·2039	1·1998	1·1957	1·1916	1·1876	1·1835	1·1794
132	1·1754	1·1713	1·1673	1·1633	1·1592	1·1552	1·1512	1·1472	1·1432	1·1393
133	1·1353	1·1313	1·1274	1·1234	1·1195	1·1156	1·1116	1·1077	1·1038	1·0999
134	1·0960	1·0922	1·0883	1·0844	1·0806	1·0767	1·0729	1·0690	1·0652	1·0614
135	1·0575	1·0537	1·0499	1·0461	1·0423	1·0385	1·0347	1·0309	1·0272	1·0234
136	1·0196	1·0159	1·0121	1·0084	1·0047	1·0009	·9972	·9935	·9898	·9861
137	·9824	·9787	·9751	·9714	·9678	·9641	·9605	·9568	·9532	·9496
138	·9459	·9423	·9387	·9351	·9315	·9279	·9243	·9207	·9172	·9136
139	·9100	·9065	·9029	·8994	·8959	·8923	·8888	·8853	·8818	·8782
140	·8747	·8712	·8677	·8642	·8607	·8572	·8538	·8503	·8468	·8434
141	·8399	·8364	·8330	·8296	·8261	·8227	·8193	·8159	·8125	·8091
142	·8057	·8023	·7989	·7956	·7922	·7888	·7854	·7821	·7787	·7754
143	·7720	·7687	·7654	·7620	·7587	·7554	·7521	·7488	·7454	·7421
144	·7388	·7355	·7322	·7289	·7256	·7223	·7191	·7158	·7125	·7093
145	·7060	·7028	·6996	·6963	·6931	·6899	·6867	·6834	·6802	·6770
146	·6738	·6706	·6674	·6642	·6610	·6578	·6546	·6514	·6483	·6451
147	·6419	·6387	·6356	·6324	·6293	·6261	·6230	·6198	·6167	·6136
148	·6104	·6073	·6042	·6011	·5980	·5949	·5918	·5887	·5856	·5825
149	·5794	·5763	·5732	·5701	·5671	·5640	·5609	·5579	·5548	·5518
150	·5487	·5457	·5426	·5396	·5366	·5335	·5305	·5275	·5244	·5214
151	·5184	·5154	·5124	·5094	·5064	·5034	·5004	·4974	·4944	·4914
152	·4884	·4854	·4824	·4795	·4765	·4735	·4705	·4676	·4646	·4617
153	·4587	·4558	·4528	·4499	·4470	·4440	·4411	·4382	·4353	·4323
154	·4294	·4265	·4236	·4207	·4178	·4149	·4120	·4091	·4062	·4033
155	·4004	·3975	·3946	·3918	·3889	·3860	·3831	·3803	·3774	·3745
156	·3717	·3688	·3660	·3632	·3603	·3575	·3547	·3518	·3490	·3462
157	·3433	·3405	·3377	·3349	·3320	·3292	·3264	·3236	·3207	·3179
158	·3151	·3123	·3095	·3067	·3039	·3012	·2984	·2956	·2928	·2901
159	·2873	·2845	·2818	·2790	·2763	·2735	·2707	·2680	·2652	·2625
160	·2597	·2570	·2542	·2515	·2488	·2460	·2433	·2406	·2378	·2351
161	·2324	·2297	·2270	·2243	·2216	·2189	·2162	·2135	·2108	·2081
162	·2054	·2027	·2000	·1973	·1947	·1920	·1893	·1866	·1839	·1813
163	·1786	·1759	·1733	·1706	·1680	·1653	·1627	·1600	·1574	·1548
164	·1521	·1495	·1469	·1442	·1416	·1390	·1364	·1338	·1311	·1285
165	·1259	·1233	·1207	·1181	·1155	·1129	·1103	·1077	·1051	·1026
166	·1000	·0974	·0949	·0923	·0897	·0872	·0846	·0821	·0795	·0770
167	·0745	·0720	·0695	·0669	·0644	·0619	·0594	·0569	·0543	·0518
168	·0493	·0468	·0443	·0418	·0393	·0368	·0343	·0318	·0294	·0269
169	·0244	·0220	·0195	·0171	·0146	·0122	·0098	·0073	·0049	·0024
170	·0000									

(*To be continued.*)

ON

THE CLASSIFICATION OF BATTERIES OF FIELD ARTILLERY BY ORDER OF MERIT IN SHOOTING.

BY

CAPTAIN HIME, R.A., F.S.S.

"Todtfahren und todtreiten kann keine . . Artillerie den Feind . . . aber todtschiessen muss sie den Feind können, daher nie aufhören, Artillerie zu sein."—*Grävenitz.*

Everyone is aware of the extraordinary impetus given to musketry practice in our Infantry by the classification of battalions according to their figure of merit, and the annual publication of the result in General Orders. So keen is the emulation that a recognised inter-regimental competition has been set afoot among the officers, and rifle-matches frequently take place not only between the N.C. officers and men of the same battalion, but between N.C. officers and men of different battalions. Every officer, N.C. officer, and private feels that to a certain degree, however small that degree may be, the position of his battalion in the annual list depends upon his individual exertions; and, one and all, they task their energies to the utmost to raise the figure of merit as high as possible. The result is that, quite apart from their rifle, our Infantry are the best-shooting Infantry in Europe. Were some such classification attempted, it cannot be for one moment doubted that a similar spirit of healthy emulation would be generated in the Artillery, and that the efficacy of our fire would be immensely increased. Owing to the real and undeniable difficulties of the case, no plan has yet, as far as I am aware, been even proposed. No one can appreciate more fully than I do myself the shortcomings, theoretical and practical, of the following plan. If, however, it should lead to the discussion of the subject and the introduction of a better plan, my object will be accomplished.

The 200 rounds allowed annually for practice consist of 6 case, 50 shrapnel, and 144 common shell.

With the case I have nothing to do: competition with it would be out of the question.

I do not propose to interfere in any way with the present competition for battery prizes, and I shall (for the sake of argument) suppose there are 10 competitors annually in each battery. As each competitor is allowed 2 shrapnel and 4 common shell (plugged), this reduces the available ammunition to 134 rounds—*i.e.*, 30 shrapnel, 50 common shell with time fuzes, and 54 common shell with percussion fuzes.

Two plans are open for the use of these 134 rounds. Either they might all be used for the purpose of inter-battery competition—which of course must take place at known ranges—or a part might be used for practice at unknown ranges, and the rest reserved for inter-battery competition. The latter plan seems to be the best; and I would suggest that the 50 common shell with time fuzes be used for competition practice at unknown ranges between the three divisions of the battery, under any arrangements the Major might think fit to adopt. This is a mere suggestion, however. I am not concerned with this question, my object being to point out how inter-battery competition might be carried out.

Supposing, however, this or some similar arrangement to be adopted, the ammunition for inter-battery competition would consist of 30 shrapnel and 54 common shell with percussion fuzes. How should this ammunition be expended?

Land and Sea Ranges.

I confess that I am unable to suggest a plan for sea ranges—*i.e.*, when practice is carried on against a buoy floating on the water. From the necessities of the case, the "unders" and "overs," "rights" and "lefts," given in the Battery and Range Reports for such practice are pure guess-work; and it would be manifestly unfair to compare such practice with the carefully measured practice of batteries using land ranges. Let us hope that the days of sea-range practice are numbered.

16-Prs. and 9-Prs.

It would be obviously unfair to tabulate together the practice of batteries armed with different guns. Two classification lists, then, would be required—one for 16-prs., the other for 9-prs.

Shrapnel and Common Shell.

I believe there are no known means of comparing the relative efficacy of shrapnel and common shell. Their objects are, indeed, so different that it would be unwise to set up a standard of comparison between them. Instead, then, of attempting an apparent impossibility, I propose that the annual classification lists should be of a twofold form—one side showing the order of merit in shrapnel fire, the other side in common shell fire. I append such a form, to give an idea of what I mean.

To return to the chief question in hand—how are the 30 shrapnel and 54 common shell with percussion fuzes to be fired so as to admit of a trustworthy comparison being instituted between the shooting qualifications of the men of one battery and those of another?

Shrapnel.

With shrapnel our course is simple. Let the 30 rounds be fired against three (or more) 8-ft. targets of ½-in. deal, placed side by side,

or with certain intervals between them, at a long range—say 1800 yds.—and the *holes* carefully counted afterwards. All we have to remember is, that the range must be the same for all batteries, and that it must be a long one; for if a short range be used, the targets will be so riddled that it will be impossible to count the holes fairly. By counting the *holes* instead of the *hits*, we include *penetration* as well as *accuracy*.

Common Shell.

From the nature of the case, practice with common shell is more difficult to estimate than that with shrapnel. One battery may drop all its common shell close round the target without hitting it, and count nothing; while another may send a few shell through, for which it counts, and drive the rest far and wide. In such a case, the practice of the first battery is obviously better than that of the second; how is the comparative value of the practice, then, to be estimated?

All we have to do is to lay down a standard range of, say, 1800 yds. for all batteries, and mark, by means of eight pegs, a circle of given radius—say 20 yds. round a target of the ordinary dimensions. The practice with the common shell can be then carried out in the usual way, and with the present Battery and Range Reports, with the exception of two small particulars. The guns should be laid on the centre of the *bottom* of the target, not on the bull's eye; and the officer on range duty should note in the column of remarks the number of shell which fall within the circle. From this simple *datum*—the number of shell, out of a given number of rounds, which fall within the radius of a given circle—may be calculated in five minutes the radius of the "probable circle," which I propose as the standard of merit of each battery. The "probable circle," I need hardly explain, is that circle, at a given range, within which it is even betting that half the shell will fall.* The smaller this radius, of course, the better the shooting. I must point out that there is no connection whatever between the "probable circle" of a battery and the "probable rectangle" of a gun, except in so far that both are calculated according to the principles of the theory of Probability. The "probable circle" is a standard for comparing the efficiency of shooting of the collective *personnel* of different batteries, the gun being eliminated from the question as far as possible; while the "probable rectangle" is a standard of comparison between different *guns*, the *personnel* being eliminated as far as possible.

It may be asked, Why take the trouble of calculating the radius of the probable circle at all? Why not rest satisfied with the number of shell which fall within the circumference of the circle pegged out round the target, just as in the case of shrapnel we were contented with the number of holes in the target? The reason is this:—With shrapnel considerable expense would be incurred in providing proper targets, &c., and the measurements and calculations requisite to determine any "probable" figure would involve a vast amount of trouble and time. There would be little or no return, too, for all this trouble, time, and expense; for the result would be practically almost useless.

* See "La Dispersion Naturelle des Projectiles," par A. van Muyden, Capitaine d'Artillerie. Lausanne, 1876, p. 12, note 1.

On the other hand, the determination of the probable circle in the case of common shell with percussion fuzes involves neither trouble, time, nor expense; and the length of its radius gives a clear and definite idea not only of the *relative*, but of the *absolute* value of the practice of a battery at the standard range. The number of shot which fall within the circle pegged out round the target (which may be called the "standard circle") furnishes us no doubt with as reliable a standard of comparison of the relative efficacy of fire of different batteries as the probable circle; but it is far from being so convenient a standard. It is much easier to remember that 31 yds. is the radius of the probable circle at the standard range, than to remember that the battery put 7 shot out of 40 into the standard circle at the standard range. If the number of shot which fall within the standard circle be somewhat inferior to the probable circle as a means of estimating the *relative* practice of a battery, it is infinitely inferior as a means of estimating the *absolute* value of the practice of a battery. Nothing can be vaguer or more indefinite than to be told that a battery put 7 shots out of 40 into a circle of 34 yds.' radius at 2000 yds.: nothing can be more definite or precise than to be told that the radius of the probable circle is 31 yds. at 2000 yds. In fact, if we know the radius of the probable circle at a given range, we know all that needs to be known about the practice at that range under ordinary circumstances. Further, knowing the radius of the probable circle at a given range, we can calculate the probability of throwing a shell into any other circle of given radius at that range—say the circle occupied by a gun-carriage in action. The probable circle, then, is in every way superior to the number of shell which fall within the standard circle as a means of classifying batteries by order of merit in shooting.

Suppose, for the sake of example, 1800 yds. to be the standard range laid down for all 9-pr. batteries for competition common shell practice, and 20 yds. to be the radius of the standard circle pegged out on the ground round the target. Suppose, further, that 10 shell out of 50 fired, or 20 per cent., fall within the circle. The radius of the probable circle is calculated from the formula

$$R = r\sqrt{\frac{-\log 2}{\log m}};$$

where r is the radius of the circle pegged out, and m is the per-centage of *misses*.

In the present case, $r = 20$ yds., and $m = \frac{80}{100} = \cdot 8$. Then

$$R = 20\sqrt{\frac{-\cdot 30103}{1\cdot 90309}} = 20\sqrt{\frac{-\cdot 30103 \times 100{,}000}{1\cdot 90309 \times 100{,}000}}$$

$$" = 20\sqrt{\frac{-30103}{\cdot 90309 \times 100{,}000 - 1 \times 100{,}000}} = 20\sqrt{\frac{30103}{9691}}$$

$$" = 20\sqrt{3\cdot 12} = 35\cdot 2 \text{ yds.}$$

Such is the plan I propose for a classification of batteries according to order of merit in shooting. It is simple; it is inexpensive; it does not increase the time required for annual practice; it involves no trouble; and it does not demand one-thousandth part of the calcu-

lations required to tabulate the practice of a battalion of Infantry. By adopting it, or some better plan, we shall be acting in the spirit which dictated Grävenitz' memorable words to a battery of Prussian Horse Artillery which made a notable failure at practice :—"You cannot ride the enemy down, nor can you drive him down; but if you are to remain Artillery, you must be able to shoot him down."

WOOLWICH,
Sept. 26, 1877.

Form of Classification Return.

INTER-BATTERY COMPETITION, 187 . 9-PR., 6 CWT. Range, 2000 yds.				
Shrapnel.	No. of holes in target.	Order of merit.	Radius of probable circle.	Common shell.
C Battery, 1st Brigade.	121	1	30·5 yds.	L Battery, 2nd Brigade.
L " 2nd "	112	2	31·0 "	N " " "
N " " "	100	3	33·2 "	C " 1st "
I " 6th "	98	4	35·0 "	K " 5th "
K " 5th "	80	5	39·7 "	I " 6th "
&c.	&c.	&c.	&c.	&c.

A corresponding form would be made out for 16-prs.

OCCASIONAL NOTE.

BY

CAPTAIN HIME, R.A.

HOW TO FIND THE DIFFERENCE IN HEIGHT OF THE GUN WHEELS.

THE following rule is shorter, simpler, and more correct than any I have ever seen tried :—

Find by the clinometer the inclination of the horizontal line on the face of the muzzle of the gun. The inclination of this line *in degrees* is equal to the difference in height of the wheels *in inches*.

PRINCIPLES OF GUNNERY.

RIFLED ORDNANCE.

BY

CAPTAIN J. SLADEN, R.A.

PROFESSOR OF ARTILLERY, R.M. ACADEMY, WOOLWICH.

(*Continued from p. 253.*)

CHAPTER VI.

TRAJECTORIES.

Unresisted Projectile.—Symbols used.—Equations of Motion of an Unresisted Projectile.—Equation of the Trajectory.—Elementary Discussion of the Conditions of Motion.—The Range on Horizontal Plane in terms of Muzzle Velocity and Angle of Departure.—The Time of Flight on a Horizontal Plane in terms of Muzzle Velocity and Angle of Departure.—The Projectile reaches its Highest Point at one-half of its Range on the Horizontal Plane, and in one-half of its total Time of Flight.—The Height of the Trajectory at any given time.—The Maximum Height of Trajectory.—The Inclination of the Projectile to the Horizontal Line in the Plane of the Trajectory.—Approximate Solution of Low-Angle Trajectories.—Angle of Descent.—Maximum Height of Trajectory.—Method of Finding the "Dangerous Distance," or the Distance in which an Object of given height would be struck, under given conditions.—Method of Finding Height of Trajectory at given Distances.—Motion of a Projectile in the Air.—Equations of Motion.—The Velocity at the Vertex of the Trajectory.—Bashforth's Method of Solution.—Niven's Method of Solution.—Practical Examples.

Unresisted projectile.

BEFORE discussing the motion of a projectile in the air, it will be necessary first to consider the simpler case in which the resistance of the air is neglected, and the projectile is supposed to move without any resistance.

Symbols used.

The following symbols will be used in this branch of the subject:—

v for the velocity of the projectile at any point of the trajectory,
V " muzzle velocity,
ϕ " inclination of the direction of motion to the horizontal line in the plane of the trajectory,
α " angle of departure,
t " time,
x " horizontal distance from some fixed point,
y " vertical distance,
g " acceleration due to gravity.

Equations of motion of an unresisted projectile.

The equations of motion, then, in a horizontal and vertical direction will be

$$\frac{d^2x}{dt^2} = 0, \text{ and } \frac{d^2y}{dt^2} = -g.$$

Integrating,

$$\frac{dx}{dt} = \text{const.} = V\cos\alpha,$$

$$\text{and } \frac{dy}{dt} = \text{const.} - gt = V\sin\alpha - gt.$$

Integrating again,

$$x = Vt \cos \alpha, \quad \ldots\ldots(1)$$

$$y = Vt \sin \alpha - \tfrac{1}{2}gt^2; \quad \ldots\ldots(2)$$

Equation of the trajectory.

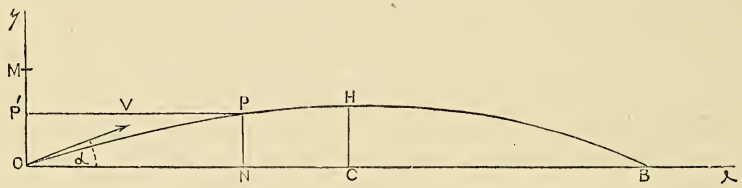
or, eliminating t between equations (1) and (2),

$$y = x \tan \alpha - \frac{gx^2}{2V^2 \cos^2 \alpha}; \quad \ldots\ldots(3)$$

which is the equation of the trajectory of an unresisted projectile.

Elementary discussion of the conditions of motion.

The same results may be obtained more simply by considering the conditions of motion. Thus, suppose (x, y) the co-ordinates of the



projectile (P) at time t. Then

$$ON = x,$$

$$NP = y,$$

$$\text{horizontal velocity at muzzle} = V \cos \alpha;$$

and since there is no resistance, and gravity acts only in a *vertical* direction,

the horizontal velocity at any point in the trajectory is the same, and equal to $V \cos \alpha$.

Again,

$$\text{vertical velocity at muzzle} = V \sin \alpha.$$

This vertical velocity is diminished by gravity acting vertically downwards—*i.e.*, by gt in time t—so that

$$\text{vertical velocity at any time, } t, \text{ is equal to } V \sin \alpha - gt.$$

The horizontal velocity being constant, and equal to $V \cos \alpha$, it follows that

$$\text{the horizontal distance } (ON) \text{ traversed by the projectile in time } t$$

$$= V \cos \alpha \times t;$$

$$\text{or } x = Vt \cos \alpha, \quad \ldots\ldots(1)$$

In the same way, if gravity were not acting,

the vertical distance traversed in time t would be

$$V \sin \alpha \times t;$$

or $$OM = Vt \sin \alpha.$$

This distance is diminished by the distance that would be traversed by the projectile falling freely under gravity in time t.

This latter distance, $MP' = \frac{1}{2}gt^2$. (*Vide* Elementary Treatises on Dynamics). Hence,

$$PN = P'O = OM - MP';$$

$$\text{or } y = Vt \sin \alpha - \tfrac{1}{2}gt^2. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

By eliminating t, as before, the equation of the trajectory of an unresisted projectile is

$$y = x \tan \alpha - \frac{gx^2}{2V^2 \cos^2 \alpha}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The trajectory is a parabola, with the axis vertical, as in the figure.

To find the range on a horizontal plane passing through the muzzle of the gun, let $y = 0$ in equation (3), then

The range on horizontal plane in terms of muzzle velocity and angle of departure.

$$gx = 2V^2 \sin \alpha \cos \alpha;$$

or if X denote the range,

$$X = \frac{2V^2 \sin \alpha \cos \alpha}{g} = \frac{V^2 \sin 2\alpha}{g}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

It is evident that for a given muzzle velocity, V, the range will be the greatest when $\sin 2\alpha = 1$, *i.e.* when $2\alpha = 90°$ or $\alpha = 45°$.

Again, if T be the time of flight for range X, since horizontal velocity, $V \cos \alpha$, is constant,

The time of flight on a horizontal plane in terms of muzzle velocity and angle of departure.

$$X = VT \cos \alpha;$$

$$\text{or } T = \frac{X}{V \cos \alpha} = \frac{2V^2 \sin \alpha \cos \alpha}{Vg \cos \alpha} = \frac{2V \sin \alpha}{g}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Since the horizontal velocity, $V \cos \alpha$, is constant, it is evident that the projectile will traverse the horizontal distance $\frac{X}{2}$ in time $\frac{T}{2}$.

The projectile reaches its highest point at one-half of its range on the horizontal plane, and in one-half of its total time of flight.

Bisect OB in C, then

$$OC = CB = \frac{X}{2}.$$

Draw CH perpendicular to OB, cutting the trajectory in H.

Since vertical velocity at any time t

$$= V \sin \alpha - gt,$$

therefore vertical velocity at time $\frac{T}{2}$

$$= V \sin \alpha - \frac{gT}{2}.$$

But at highest point this must be zero; so that

$$V \sin \alpha - \frac{gT}{2} = 0,$$

$$\text{or } \frac{T}{2} = \frac{V \sin \alpha}{g};$$

i.e., the projectile has traversed, when it reaches its *highest* point, *one-half of its range* on the horizontal plane in *one-half of the total time of flight.*

The height of the trajectory at any given time.

The height of the trajectory at any time may be found when the whole time of flight is known, thus:

Suppose T the whole time of flight; then from equation (5),

$$V = \frac{gT}{2 \sin \alpha}.$$

Substituting this value of V in equation (2),

$$y = Vt \sin \alpha - \tfrac{1}{2}gt^2 = \frac{g}{2} Tt - \tfrac{1}{2}gt^2;$$

$$\text{or } y = \frac{gt}{2}(T - t). \quad \ldots\ldots\ldots\

If ϕ be the inclination of the direction of motion of the projectile to the horizontal line in the plane of the trajectory, at any time, t, then

The inclination of the projectile to the horizontal line in the plane of the trajectory.

$$\tan\phi = \frac{dy}{dx} = \frac{\frac{dy}{dt}}{\frac{dx}{dt}} = \frac{\text{vertical velocity at that time}}{\text{horizontal velocity at that time}}; \quad \ldots\ldots\ldots\ldots(7)$$

$$\text{or } \tan\phi = \frac{V\sin\alpha - gt}{V\cos\alpha} = \frac{(T-2t)}{T\cot\alpha}.$$

If β be the angle of descent at time T, then $t = T$; then

$$\tan\beta = \frac{T-2T}{T\cot\alpha} = -\tan\alpha.$$

i.e., with an unresisted projectile the angle of descent is equal to the angle of departure.

The above formulæ, (6) and (7), are very useful for the approximate calculation of the path of a projectile in the air for low-angle trajectories, where the *vertical* velocity may be considered as practically unaffected by the resistance of the air.

Approximate solution of low-angle trajectories.

For angles of elevation up to 5° the trajectory for a given range may be determined with considerable accuracy by the use of Tables I. and II. (Chap. V., p. 55).

The remaining velocity at the end of the range is found by Table I. from the equation

$$\frac{d^2}{w}S = S_v - S_V,$$

$$\text{or } S_v = S_V + \frac{d^2}{w}S,$$

on the supposition that the projectile is moving in a horizontal line unaffected by gravity.

Thus, if O be the point of projection, and B the point of impact on the horizontal line through O, then the projectile is supposed to move along OB, and the remaining velocity at B is found from the above equation by means of Table I. Then from equation,

$$\frac{d^2}{w}T = t_v - T_V,$$

and by means of Table II. T (the time of flight over OB) is found.

The action of gravity must now be considered.

For low angles of elevation the vertical velocity of the projectile is small, and the resistance of the air to the projectile in the vertical direction may be neglected; so that all the conditions shown to hold in the vertical plane in the case of an unresisted projectile hold also in this case.

The projectile will ascend approximately for half the time of flight, $= \frac{T}{2}$, and descend for the same time. It will be at its maximum height (H) at the time $\frac{T}{2}$; so that, as before,

$$HC = \frac{gT^2}{8}.$$

In the same way, by Table II. the time over OP and PB may be found, when the velocity at O and the distances ON and NB are known.

Suppose

time over $OP = t$,

" $OB = T$,

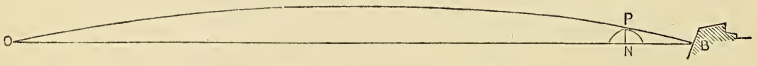
then " $PB = T - t = t'$, suppose;

then height $NP = \frac{g}{2} t\,(T - t)$, from equation (6),

$$= \frac{g}{2} tt'.$$

Example 1.—A common shell, fired from a 64-pr. M.L. siege gun with a charge of 12 lbs. of powder, was observed to strike the crest of a traverse in 3·2 secs. Find approximately the range, and what vertical distance below the crest of the traverse the shell would strike an escarp 200 ft. beyond. Muzzle velocity = 1457 f.s., weight of shell = 64 lbs., diameter of shell = 6·22 ins.

The remaining velocity at P can be found thus:



$$T_v = T_V + \frac{d^2}{w} T = T_{1457} + \frac{(6{\cdot}22)^2}{64} \times 3{\cdot}2$$

$$= {\cdot}6834 + 1{\cdot}9344 = 2{\cdot}6178;$$

$$\therefore\ v = 1064 \text{ f.s.} \quad \text{(Table II.)}$$

The distance ON can then be found thus:

$$S = \frac{S_v - S_V}{\frac{d^2}{w}} = \frac{3455{\cdot}2 - 1075{\cdot}1}{{\cdot}6045} = 3937{\cdot}3 \text{ ft.} = ON,$$

the distance of the traverse from the gun.

The velocity at P being known, it is easy to find the velocity at B (200 ft. distant) thus:

$$S_{v'} = S_v + \frac{d^2}{w} S = S_{1064} + \cdot 6045 \times 200$$

$$= 3455 \cdot 2 + 120 \cdot 9 = 3576 \cdot 1;$$

so that

velocity at B or $v' = 1051$ f.s.

Now the time over PB can be found thus:

$$T = \frac{T_{v'} - T_v}{\frac{d^2}{w}} = \frac{T_{1051} - T_{1064}}{\cdot 6045} = \frac{2 \cdot 7328 - 2 \cdot 6182}{\cdot 6045} = \cdot 19 \text{ sec.}$$

Put t' for the time over PB, then

$$t' = \cdot 19 \text{ sec.}$$

But time over $OP = t = 3 \cdot 2$ secs.; so that from equation (6),

$$PN = \frac{g}{2} tt' = \frac{32 \cdot 2}{2} \times 3 \cdot 2 \times \cdot 19 = 9 \cdot 79 \text{ ft.}$$

i.e., the vertical distance below the crest of the traverse that the shell will strike an escarp 200 ft. beyond is 9·79 ft.

Angle of descent.

The approximate angle of descent at the escarp may be also found. If ϕ is the angle of descent at the escarp,

$$\tan \phi = \frac{\text{vertical velocity}}{\text{horizontal velocity}}. \quad [\textit{Vide} \text{ equation (7), p. 263}].$$

But if T be the whole time of flight, and the vertical motion be treated as for an unresisted projectile,

$$\text{vertical velocity} = \frac{gT}{2},$$

and horizontal velocity on impact is found from equation

$$T_v = T_V + \frac{d^2}{w} T,$$

so that

$$\tan \phi = \frac{g}{2} \cdot \frac{\text{total time of flight}}{\text{horizontal velocity on impact}};$$

or approximately for small angles,

$$\phi = \frac{180}{\pi} \cdot \frac{g}{2} \cdot \frac{\text{total time of flight}}{\text{horizontal velocity on impact}}.$$

In the above case,

$$T = t + t' = 3 \cdot 2 + \cdot 19 = 3 \cdot 39 \text{ secs.},$$

so that

$$\tan \phi = \frac{32 \cdot 2}{2} \times \frac{3 \cdot 39}{1051} = \cdot 05192;$$

$$\text{or } \phi = 2^\circ\ 58'.$$

Maximum height of trajectory.

The maximum height of the trajectory may also be approximated to thus:—If T be the total time of flight,

$$\text{maximum height of trajectory} = \frac{gT^2}{8}. \quad (\textit{Vide} \text{ p. } 262).$$

$$= \frac{32{\cdot}2}{8}(3{\cdot}39)^2 = 46{\cdot}26 \text{ ft.}$$

Method of finding the "dangerous distance," or the distance in which an object of given height would be struck, under given conditions.

If $y = PN$ is the height of the object to be struck, t the time of flight over OP, and T the time of flight over the given range, OB, then from equation (6),

$$y = \frac{gt}{2}(T - t).$$

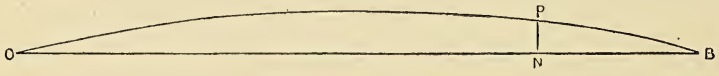
Solving the quadratic, it is found that

$$t = \frac{T}{2} \pm \sqrt{\frac{T^2}{4} - \frac{2y}{g}}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

the upper sign to be taken for the second half of the trajectory. Hence t is known in terms of the total time of flight, and the height of the object fired at.

The time over OP being known, the velocity at P can be found, whence the distance ON is known, and consequently NB—the "dangerous distance"—is known.

Example 2.—The 12·5-in. M.L. gun is fired with a battering charge so as to strike a ship on the water-line at a distance of 3000 ft. What would be the "dangerous distance," or the distance short of 3000 ft. in which the ship whose side was 8·05 ft. above the water-line would be struck somewhere on its side, under the given conditions? Muzzle velocity = 1420 f.s., weight of projectile = 802 lbs., diameter of projectile = 12·42 ins., OB = 3000 ft., PN = 8·05 ft.



The remaining velocity at B can be found thus:

$$S_v = S_V + \frac{d^2}{w} S = S_{1420} + \frac{(12{\cdot}42)^2}{802} \times 3000$$

$$= 1251{\cdot}1 + 576{\cdot}9 = 1828;$$

or $v = 1307$ f.s. (Table I.)

The time over OB can be found thus:

$$T = \frac{T_v - T_V}{\frac{d^2}{w}} = \frac{1{\cdot}2287 - {\cdot}8057}{{\cdot}1923} = 2{\cdot}2 \text{ secs.}$$

Now, to find the time the projectile would be at P, substitute $T = 2{\cdot}2$ and $y = 8{\cdot}05$ in equation (8), or

$$t = \frac{T}{2} + \sqrt{\frac{T^2}{4} - \frac{2y}{32{\cdot}2}} = 1{\cdot}1 + \sqrt{1{\cdot}21 - {\cdot}5};$$

or $t = 1{\cdot}94$ secs.

The remaining velocity at P at the end of 1·94 secs. can be found thus:

$$T_{v'} = \frac{d^2}{w} T + T_V = \frac{(12{\cdot}42)^2}{802} \times 1{\cdot}94 + T_{1420}$$

$$= {\cdot}3731 + {\cdot}8057 = 1{\cdot}1788 \text{ secs.};$$

or $v' = 1319$ f.s.

The distance travelled by the projectile in 1·94 secs. can be found thus:

$$S' = \frac{S_{v'} - S_V}{\frac{d^2}{w}} = \frac{S_{1319} - S_{1420}}{{\cdot}1923} = \frac{1762{\cdot}4 - 1251{\cdot}1}{{\cdot}1923};$$

or $S' = ON = 2659$ ft.

But from figure,

$$NB = OB - ON = 3000 - 2659 = 341 \text{ ft.};$$

or the position short of 3000 ft. in which the side of the ship would be hit is 341 ft.

Example 3.—Find the height of the trajectory of the Martini-Henry rifle for a range of 500 yds. at intervals of 100 yds. Weight of bullet $= 480$ grs. $= \frac{480}{7000}$ lbs.* $= {\cdot}06857$ lbs., diameter of bullet $= {\cdot}45$ ins., muzzle velocity $= 1353$ f.s. Method of finding height of trajectory at given distances.

The remaining velocity at 500 yds. = 1500 ft. can be found by Table I. thus:

$$S_v = S_{1353} + \frac{({\cdot}45)^2}{{\cdot}06857} \times 1500 = 1584 + 2{\cdot}953 \times 1500 = 6013{\cdot}5;$$

or remaining velocity at 500 yds. = 889 f.s.

Then time over 500 yds. can be found by Table II. thus:

$$2{\cdot}953T = T_{889} - T_{1353} = 5{\cdot}2762 - 1{\cdot}0461 = 4{\cdot}2301;$$

or time over 500 yds. = 1·432 secs.

---

* 7000 grs. Troy make 1 lb. Avoirdupois.

The remaining velocity at 100 yds. = 300 ft. can be found by Table I. thus:

$$S_v = S_{1353} + 2{\cdot}953 \times 300 = 1584 + 885{\cdot}9 = 2469{\cdot}9 \text{ ft.}$$

or velocity at 100 yds. = 1198 f.s.

Then time over 100 yds. can be found by Table II. thus:

$$2{\cdot}953T = T_{1198} - T_{1353} = 1{\cdot}7416 - 1{\cdot}0461 = {\cdot}6955;$$

or time over 100 yds. = ·2356 sec.

Then the height of the trajectory at 100 yds. can be found by substituting in the formula

$$y = \frac{gt}{2}(T - t);$$

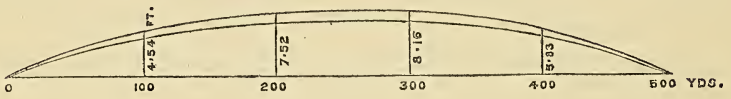
where $T = 1{\cdot}432$ and $t = {\cdot}2356$.

Thus,

$$y_{100} = \frac{32{\cdot}19 \times {\cdot}2356}{2} \times 1{\cdot}1964 = 4{\cdot}537 \text{ ft.}$$

In a similar manner, the height of the trajectory at 200, 300, and 400 yds. may be found.

Trajectory of Martini-Henry and Mauser Rifle at 500 yds.



Martini-Henry.				Mauser.		
Distance.	Velocity.	Time of flight.	Height of trajectory.	Velocity.	Time of flight.	Height of trajectory.
yds.	f.s.	secs.	ft.	f.s.	secs.	ft.
0.....	1353	·0000	0	1526	·0000	0
100.....	1198	·2356	4·54	1312	·2127	3·95
200.....	1075	·5021	7·52	1143	·4578	6·70
300.....	994	·7934	8·16	1023	·7358	7·47
400.....	937	1·1040	5·83	950	1·0400	5·47
500.....	889	1·4320	0	892	1·3670	0
Weight of bullet = 480 grs.; diameter of bullet = ·45 in.				Weight of bullet = 382 grs.; diameter of bullet = ·435 in.		

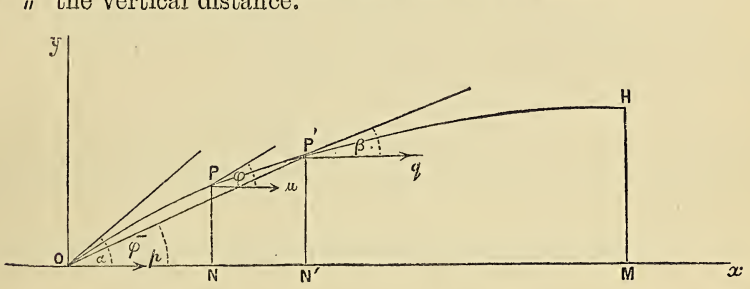
THE MOTION OF A PROJECTILE IN THE AIR WILL NOW BE CONSIDERED.

Motion of a projectile in the air.

It is assumed that the resistance of the air acts along the tangent to the trajectory of the projectile. This assumption is no doubt very nearly correct for flat trajectories, but it cannot be relied upon with certainty for high-angle trajectories. The motion will also be assumed to take place in the plane of the trajectory. This, without doubt, is not quite correct, as it is well known that the projectile performs small gyrations round the mean path of its trajectory.

The same notation will be used as for the trajectory of an unresisted projectile.

v the velocity at any point of the trajectory,
u " horizontal component of v,
ϕ " inclination of the direction of motion to the horizontal line in the plane of the trajectory,
t " time,
x " horizontal distance from the point of projection,
y " the vertical distance.



Suppose O the point of projection, α the angle of departure, OH the ascending path of the projectile, H the vertex of the trajectory, Ox the horizontal line in the plane of the trajectory, Oy the vertical line, P the position of the projectile at any time t, u its horizontal velocity.

It is proposed now to consider the motion of the projectile over a component arc of the trajectory OP', α and β being the inclination of the direction of motion to the horizontal line Ox, at the beginning and end of the arc, p and q being the horizontal velocities—*i.e.*, the values of u—at those points.

Equations of motion.

It has been seen that for certain ranges of velocity the law of retardation may be correctly stated to vary as the cube of the velocity, or to be equal to cv^3.

The equation of motion obtained by resolution in a horizontal direction is, then,

$$\frac{d^2x}{dt^2} = \frac{du}{dt} = -cv^3 \cos\phi. \quad \text{.....(1)}$$

The equation of motion obtained by resolution in the direction of the normal to the trajectory is

$$v\frac{d\phi}{dt} = -g\cos\phi; \quad \text{.....(2)}$$

the sign on the right-hand side of the equation being negative, since ϕ diminishes as t increases.

Hence, dividing (1) by (2),

$$\frac{du}{d\phi} = \frac{cv^4}{g}; \quad \text{.....(3)}$$

or, since $v = u \sec \phi$,

$$\frac{du}{d\phi} = \frac{cu^4}{g} \sec^4 \phi;$$

$$\text{or} \quad \frac{du}{u^4} = \frac{c}{g} \sec^4 \phi d\phi.$$

Integrating,

$$\int_p^u \frac{du}{u^4} = \frac{c}{g} \int_\alpha^\phi \sec^4 \phi d\phi,$$

$$\text{or} \quad \frac{1}{u^3} - \frac{1}{p^3} = \frac{c}{g} (P_\alpha - P_\phi); \quad \text{.....(4)}$$

where $P_\alpha = 3\int_0^\alpha \sec^4 \phi d\phi = 3 \tan \alpha + \tan^3 \alpha.$

Suppose at the end of the arc OP' the horizontal velocity is q, and β the inclination of the direction of motion to the horizontal line; then, substituting,

$$\frac{1}{q^3} = \frac{1}{p^3} + \frac{c}{g} (P_\alpha - P_\beta). \quad \text{.....(5)}$$

The velocity at the vertex of the trajectory.

Suppose u_0 the velocity (horizontal) at the vertex of the trajectory, H, then it follows from the above that

$$\frac{1}{u_0^3} = \frac{1}{p^3} + \frac{c}{g} P_\alpha;$$

$$\text{or} \quad \frac{1}{p^3} = \frac{1}{u_0^3} - \frac{c}{g} P_\alpha. \quad \text{.....(6)}$$

Substituting this value of $\frac{1}{p^3}$ in equation (4), it follows that

$$\frac{1}{u^3} = \frac{1}{u_0^3} - \frac{c}{g} P_\phi = \frac{1}{u_0^3} \left(1 - \frac{cu_0^3}{g} P_\phi\right).$$

Suppose

$$\frac{cu_0^3}{g} = \gamma, \quad \text{.....(7)}$$

then

$$\frac{1}{u^3} = \frac{1}{u_0^3} (1 - \gamma P_\phi);$$

$$\text{or} \quad u = \frac{u_0}{(1 - \gamma P_\phi)^{\frac{1}{3}}}. \quad \text{.....(8)}$$

From equation (2),

$$\frac{dt}{d\phi} = -\frac{v}{g}\sec\phi = -\frac{u\sec^2\phi}{g};$$

and if T represent the time over the arc OP', integrating we have

$$T = \int_\beta^\alpha \frac{u}{g}\sec^2\phi d\phi;$$

or, substituting the value of u in equation (8),

$$T = \frac{u_0}{g}\int_\beta^\alpha \frac{\sec^2\phi d\phi}{(1-\gamma P_\phi)^{\frac{1}{3}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Again, $$\frac{dx}{dt} = u,$$

$$\therefore\ x = \int u dt = -\int \frac{u^2\sec^2\phi}{g} d\phi;$$

or if X represent the horizontal distance traversed in the arc OP',

$$X = \frac{u_0^2}{g}\int_\beta^\alpha \frac{\sec^2\phi}{(1-\gamma P_\phi)^{\frac{2}{3}}} d\phi. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Again, $$\frac{dy}{dt} = u\tan\phi;$$

so that if Y represent the vertical distance traversed in the arc OP',

$$Y = \frac{u_0^2}{g}\int_\beta^\alpha \frac{\tan\phi\sec^2\phi}{(1-\gamma P_\phi)^{\frac{2}{3}}} d\phi. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Equation (9) gives the time of the projectile over the arc OP', and equations (10) and (11) give the co-ordinates of the projectile at that time.

If the cubic law were correct for all velocities, and consequently the coefficient c constant, the range and time of flight of a projectile could each be correctly determined by this method in two operations—(1) by calculating over the arc from the point of projection to the vertex, (2) by calculating over the arc from the vertex to the point of impact.

But as this coefficient is not constant for all velocities, it becomes necessary to calculate the arcs in smaller parts, and to take the *mean value* of the coefficient for these arcs, and thus to approximate very closely to the correct solution.

Bashforth's method of solution.

The above is the solution which Bashforth has adopted in his valuable treatise on the "Motion of Projectiles,"* in which he has

* "A Mathematical Treatise on the Motion of Projectiles," by F. Bashforth, B.D., published in 1873 by Asher & Co.

given tables for the integrals in equations (9), (10), and (11) corresponding to different values of γ, between certain ranges of angle. Other subsidiary tables are given which materially shorten the calculations. A practical solution of a problem is given at p. 56 of this work.

The value of c, determined by Bashforth, is (*vide* Chap. V., p. 241)

$$c = \frac{d^2}{w} \cdot \frac{K}{(1000)^3},$$

so that equation (6) becomes

$$\left(\frac{1000}{u_0}\right)^3 = \left(\frac{1000}{p}\right)^3 + \frac{d^2}{w}\frac{K}{g} P_\alpha;$$

whence u_0 (the velocity at the vertex) is determined by taking the mean value of K over the arc.

The value of γ is then determined from equation (7) thus:

$$\gamma = \frac{d^2}{w} \cdot \frac{K}{g}\left(\frac{u_0}{1000}\right)^3.$$

The integrals $\int_\beta^\alpha \frac{\sec^2\phi}{(1-\gamma P_\phi)^{\frac{3}{2}}} d\phi$, $\int_\beta^\alpha \frac{\tan\phi \sec^2\phi}{(1-\gamma P_\phi)^{\frac{3}{2}}} d\phi$, and $\int_\beta^\alpha \frac{\sec^2\phi d\phi}{(1-\gamma P_\phi)^{\frac{1}{2}}}$ can then be found from tables at p. 40 *et seq.*, "Motion of Projectiles," and the values of T, X, and Y deduced from equations (9), (10), and (11).

For examples *vide* p. 60 *et seq.*, "Motion of Projectiles," to which treatise the reader is referred for this method of solution.

Niven's method of solution.

Another method of solution has been proposed by Mr. W. D. Niven, of Trinity College, Cambridge, late Professor of Mathematics to the Advanced Class of Royal Artillery Officers at Woolwich, based upon the experiments carried out by Professor Bashforth, and making use of his Tables (Chap. V., p. 250, &c.). It has the advantage of requiring less tabular matter for the approximate solution of problems in practical gunnery.

Using the same notation as before, and putting r for the retardation due to the resistance of the air, the equations of motion obtained by resolution in the horizontal direction and in the direction of the normal to the trajectory in the ascending branch will be, as before,

$$\frac{du}{dt} = -r\cos\phi, \quad \text{.....(i.)}$$

$$v\frac{d\phi}{dt} = -g\cos\phi. \quad \text{.....(ii.)}$$

The principle of this method of solution consists in taking the hori-

zontal velocity u as the independent variable, and expressing the four quantities ϕ, t, x, y in terms of u. Thus, dividing (i.) by (ii.),

$$\frac{du}{vd\phi} = \frac{r}{g},$$

$$\text{or } \frac{d\phi}{du} = \frac{g}{rv};$$

$$\therefore \int_\beta^\alpha d\phi = g\int_q^p \frac{du}{vr},$$

$$\text{or } \alpha - \beta = g\int_q^p \frac{du}{vr}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(a)$$

Again, from (i.),

$$T = \int_q^p \frac{du}{r\cos\phi}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(b)$$

Also, since $\frac{dx}{dt} = u$,

$$dx = udt = -\frac{udu}{r\cos\phi};$$

$$\therefore X = \int_q^p \frac{udu}{r\cos\phi}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(c)$$

Again, since $\frac{dy}{dt} = u\tan\phi$,

$$dy = u\tan\phi\, dt = \frac{u\tan\phi\, du}{r\cos\phi};$$

$$\therefore Y = \int_q^p \frac{u\tan\phi\, du}{r\cos\phi}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(d)$$

The above equations—(a), (b), (c), (d)—are the most general forms of the integrals which give the characteristic quantities in the motion of a projectile. In order to solve them, the form of the quantity r as a function of the velocity must be experimentally determined—*i.e.*, the law of the resistance of the air to the projectile must be known. It has already been shown how this has been accomplished by Mr. Bashforth; but as unfortunately the cubic law only holds for a limited range of velocity, there is no simple formula for r, so that it is necessary to find approximate values of the above integrals. This has already been done when the function of the angle ϕ is outside the integral for the integrals (c), (d) in Table I., and for the integral (b) in Table II. (Chap. V., p. 250, &c.); and Table III. (p. 278) gives, in like manner, the approximate value of the integral in equation (a).

In order to make use of these approximations in the solution of examples, it is necessary to divide the trajectory into arcs as before, and to determine the *mean value* of the quantity ϕ over that arc. For instance, in the figure at p. 269, in the arc OP', the mean value of ϕ, varying from α to β, is the inclination of the chord OP' to the horizontal line. Let this be denoted by $\bar{\phi}$.

The method of finding the mean value of ϕ is too difficult to be given in this treatise; but the reader is referred to a paper by Mr. Niven "On the Calculation of the Trajectories of Shot," in the "Proceedings of the Royal Society," No. 181, 1877.

The inclination $\bar{\phi}$ of the chord OP' is given approximately by

$$\bar{\phi} = \frac{\alpha + \beta}{2} + \tfrac{1}{3}\frac{p - q}{p + q}(\alpha - \beta)$$

for the ascending branch, and

$$\bar{\phi} = \frac{\alpha + \beta}{2} - \tfrac{1}{3}\frac{p - q}{p + q}(\beta - \alpha)$$

for the descending branch.

Without going minutely into the whole treatment of the integrals in equations (a), (b), (c), (d), a general explanation of the method of solution will now be given.

Take, for example, equation (c),

$$X = \int_q^p \frac{u\,du}{r\cos\phi}.$$

Now, r is some function of v—call it $f(v)$; so that equation (c) may be written

$$X = \int_q^p \frac{u\,du}{f(v)\cos\phi} = \int_q^p \frac{u\,du}{f(u\sec\phi)\cos\phi} \text{ (since } v = u\sec\phi).$$

If $\bar{\phi}$ is a mean value of the quantity ϕ over the given arc requiring discussion and determination for this particular integral,

then
$$X = \int_q^p \frac{u\,du}{f(u\sec\bar{\phi})\cos\bar{\phi}}.$$

Suppose now $u = v^*\cos\bar{\phi}$, then $v = u\sec\bar{\phi}$, and $du = \cos\bar{\phi}\,dv$; so that

$$X = \int_{q\sec\bar{\phi}}^{p\sec\bar{\phi}} \frac{v\cos\bar{\phi}\,dv}{f(v)}.$$

Now, the value of $f(v)$, determined by Bashforth,

$$= cv^3 = \frac{d^2}{w}K\left(\frac{v}{1000}\right)^3;$$

so that

$$X = \cos\bar{\phi}\int_{q\sec\bar{\phi}}^{p\sec\bar{\phi}} \frac{v\,dv}{\frac{d^2}{w}K\left(\frac{v}{1000}\right)^3};$$

or
$$\frac{d^2}{w}X = \cos\bar{\phi}\int_{q\sec\bar{\phi}}^{p\sec\bar{\phi}} \frac{(1000)^3\,dv}{Kv^2}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(e)$$

* It is scarcely necessary to warn the reader that the v in this substitution is not the same as the v used above for the velocity. It is of course indifferent what symbol may be used in place of the new v, as it always occurs inside of a definite integral.

Similarly,

$$\frac{d^2}{w} Y = \sin \bar{\phi} \int_{q \sec \bar{\phi}}^{p \sec \bar{\phi}} \frac{(1000)^3 \, dv}{Kv^2}. \quad \ldots\ldots\ldots\ldots\ldots\ldots (f)$$

It will be seen that the values of X and Y both depend on the value of the integral

$$\int_v^V \frac{(1000)^3 \, dv}{Kv^2} = S_v - S_V,$$

given in Table I. (p. 250); so that equations (e) and (f) may be written

$$\frac{d^2}{w} X = \cos \bar{\varphi} \, (S_{q \sec \bar{\phi}} - S_{p \sec \bar{\phi}}), \quad \ldots\ldots\ldots\ldots\ldots\ldots (A)$$

$$\frac{d^2}{w} Y = \sin \bar{\varphi} \, (S_{q \sec \bar{\phi}} - S_{p \sec \bar{\phi}}). \quad \ldots\ldots\ldots\ldots\ldots\ldots (B)$$

This mode of treatment of the X and Y integrals may be employed in the case of the time integral, equation (b)—viz.,

$$T = \int_q^p \frac{du}{f(v) \cos \phi}.$$

This may be reduced to

$$\frac{d^2}{w} T = \int_{q \sec \bar{\phi}}^{p \sec \bar{\phi}} \frac{(1000)^3 \, dv}{Kv^3}; \quad \ldots\ldots\ldots\ldots\ldots\ldots (g)$$

$$\text{or} \quad \frac{d^2}{w} T = T_{q \sec \bar{\phi}} - T_{p \sec \bar{\phi}}. \quad \ldots\ldots\ldots\ldots\ldots\ldots (C)$$

the value of which is given in Table II. (p. 252).

The mean angle $\bar{\phi}$ for the time integral is not, however, quite the same as that for the distance integrals, being approximately

$$\bar{\phi}' = \frac{\alpha + \beta}{2} + \tfrac{1}{6} \frac{p - q}{p + q} (\alpha - \beta)$$

in the ascending branch, and

$$\bar{\phi}' = \frac{\alpha + \beta}{2} - \tfrac{1}{6} \frac{p - q}{p + q} (\beta - \alpha)$$

in the descending branch.

It will be observed that the determination of the distance and time integrals both depend on the value of the quantity $q \sec \bar{\phi}$, of which q is still unknown. This can be found by the consideration of equation (a).

$$\alpha - \beta = g \int_q^p \frac{du}{vr} = g \int_q^p \frac{du}{vf(v)};$$

$$\text{or} \quad \alpha - \beta = g \int_q^p \frac{du}{u \sec \phi f(u \sec \phi)}.$$

As before, suppose ϕ has a mean value $\bar{\phi}$, and suppose $\alpha - \beta$ expressed in degrees $= D$; then

$$D = \frac{180g}{\pi} \int_q^p \frac{du}{u \sec \bar{\phi} f(u \sec \bar{\phi})}.$$

Put $u = v \cos \bar{\phi}$, then the equation becomes

$$D \sec \bar{\phi} = \frac{180g}{\pi} \int_{q \sec \bar{\phi}}^{p \sec \bar{\phi}} \frac{dv}{vf(v)}.$$

But by Bashforth's law,

$$f(v) = \frac{d^2}{w} K \left(\frac{v}{1000}\right)^3;$$

so that

$$\frac{d^2}{w} D = \cos \bar{\phi} \cdot \frac{180g}{\pi} \int_{q \sec \bar{\phi}}^{p \sec \bar{\phi}} \frac{(1000)^3 dv}{Kv^4}. \quad \ldots\ldots\ldots\ldots (k)$$

Niven has calculated the value of the integral $\frac{180g}{\pi} (1000)^3 \int_v^{1700} \frac{dv}{Kv^4}$ (using Bashforth's value of K) for values of v down to 900. (*Vide* Table III.) Table III. connects degrees and velocity, and is denoted by D_v.

If this integral is represented by D_v, equation (k) becomes

$$\frac{d^2}{w} D = \cos \bar{\phi} \, (D_{q \sec \bar{\phi}} - D_{p \sec \bar{\phi}}). \quad \ldots\ldots\ldots\ldots (D)$$

There is no means of determining the exact value of the mean angle $\bar{\phi}$ in this case. As, however, sec ϕ varies very slowly for the greater part of the trajectory, it will suffice in this equation to put $\bar{\phi} = \frac{\alpha + \beta}{2}$ for low angles of elevation; but for high angles of elevation $\bar{\phi}$ should be more accurately determined from the formula

$$\tan \bar{\phi} = \frac{\tan \alpha + \tan \beta}{2},$$

by means of a table of natural tangents. With the aid of the D_v Table the value of q sec ϕ can be determined, and thence the value of q.

X, Y, and T can be determined by means of the equations (A), (B), and (C).

In the ascending branch, for the distance integrals, $\frac{1}{3} \frac{p-q}{p+q} (\alpha - \beta)$ must be added to the value of $\bar{\phi}$ so found, and for the time integrals, $\frac{1}{6} \frac{p-q}{p+q} (\alpha - \beta)$ must be added.

In the descending branch, from the value of $\bar{\phi}$ found as above, for

the distance integrals, $\frac{1}{3}\frac{p-q}{p+q}(\beta-\alpha)$ must be subtracted, and for the time integrals, $\frac{1}{6}\frac{p-q}{p+q}(\beta-\alpha)$ must be subtracted.

THE EQUATIONS AND STEPS WILL NOW BE WRITTEN IN THE ORDER OF CALCULATION.

$$\bar{\varphi}_1 = \frac{\alpha+\beta}{2} \text{ for low angles of elevation,}$$

$$\text{or } \tan\bar{\varphi}_1 = \frac{\tan\alpha+\tan\beta}{2} \text{ for high angles of elevation.}$$

If V is the muzzle velocity of the projectile, and α the angle of departure, then

$$p = V\cos\alpha, \text{ and } p\sec\bar{\varphi}_1 = V\cos\alpha\sec\bar{\varphi}_1;$$

then $q\sec\bar{\varphi}_1$ can be found from Table III. by equation (D) thus:

$$D_{q\sec\bar{\varphi}_1} = \frac{d^2}{w} D\sec\bar{\varphi}_1 + D_{p\sec\bar{\varphi}_1};$$

where $D = \alpha - \beta$ in degrees.

The correct value of $\bar{\varphi}$ can be found in the ascending branch thus:

$$\bar{\varphi} = \bar{\varphi}_1 + \tfrac{1}{3}\frac{p-q}{p+q}(\alpha-\beta);$$

then X can be found from equation (A) thus:

$$X = \frac{w}{d^2}\cos\bar{\varphi}\,(S_{q\sec\bar{\varphi}} - S_{p\sec\bar{\varphi}}),$$

and Y can be found from equation (B) thus:

$$Y = \frac{w}{d^2}\sin\bar{\varphi}\,(S_{q\sec\bar{\varphi}} - S_{p\sec\bar{\varphi}}).$$

For the correct determination of the time,

$$\bar{\varphi}' = \bar{\varphi}_1 + \tfrac{1}{6}\frac{p-q}{p+q}(\alpha-\beta);$$

but as the value of $\bar{\varphi}'$ does not occur outside the equation in the time integral, the value $\bar{\varphi}_1$ may be taken, and will give accurate results.

Then T can be found from equation (C) thus:

$$T = \frac{w}{d^2}(T_{q\sec\bar{\varphi}'} - T_{p\sec\bar{\varphi}'}).$$

This process will be repeated for each component arc in the ascending branch. A similar process is carried on for the descending branch; the sum of all the X's in the component arcs gives the range, and the sum of all the T's gives the time of flight.

TABLE III.

Degree and Velocity Table. $\frac{d^2}{w} D = D_v - D_V$.

v.	0	1	2	3	4	5	6	7	8	9
f.s.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.
90	8·3380	8·2955	8·2529	8·2104	8·1678	8·1253	8·0827	8·0402	7·9976	7·9551
91	7·9125	7·8714	7·8302	7·7890	7·7479	7·7066	7·6654	7·6242	7·5830	7·5418
92	7·5006	7·4627	7·4248	7·3868	7·3489	7·3110	7·2730	7·2351	7·1972	7·1592
93	7·1213	7·0851	7·0489	7·0127	6·9766	6·9404	6·9043	6·8681	6·8319	6·7958
94	6·7596	6·7251	6·6906	6·6561	6·6216	6·5870	6·5525	6·5180	6·4835	6·4490
95	6·4146	6·3819	6·3492	6·3166	6·2839	6·2513	6·2186	6·1860	6·1533	6·1207
96	6·0880	6·0571	6·0263	5·9954	5·9646	5·9338	5·9030	5·8722	5·8413	5·8105
97	5·7797	5·7507	5·7217	5·6927	5·6637	5·6347	5·6057	5·5767	5·5477	5·5187
98	5·4898	5·4625	5·4352	5·4079	5·3806	5·3533	5·3260	5·2987	5·2715	5·2442
99	5·2169	5·1914	5·1660	5·1405	5·1151	5·0896	5·0641	5·0387	5·0132	4·9878
100	4·9623	4·9386	4·9149	4·8912	4·8675	4·8437	4·8200	4·7963	4·7726	4·7489
101	4·7252	4·7032	4·6812	4·6591	4·6371	4·6151	4·5931	4·5711	4·5490	4·5270
102	4·5050	4·4847	4·4643	4·4440	4·4236	4·4033	4·3830	4·3626	4·3423	4·3219
103	4·3016	4·2829	4·2642	4·2456	4·2269	4·2082	4·1895	4·1708	4·1522	4·1335
104	4·1148	4·0977	4·0806	4·0635	4·0464	4·0293	4·0122	3·9951	3·9780	3·9609
105	3·9439	3·9282	3·9125	3·8968	3·8811	3·8655	3·8498	3·8341	3·8184	3·8027
106	3·7871	3·7726	3·7581	3·7436	3·7292	3·7147	3·7002	3·6857	3·6712	3·6567
107	3·6422	3·6287	3·6151	3·6016	3·5881	3·5746	3·5610	3·5475	3·5340	3·5204
108	3·5069	3·4941	3·4814	3·4686	3·4558	3·4431	3·4303	3·4175	3·4047	3·3920
109	3·3792	3·3670	3·3549	3·3427	3·3306	3·3184	3·3062	3·2941	3·2819	3·2698
110	3·2576	3·2460	3·2344	3·2228	3·2111	3·1995	3·1879	3·1762	3·1646	3·1529
111	3·1413	3·1301	3·1190	3·1078	3·0966	3·0855	3·0743	3·0631	3·0519	3·0408
112	3·0296	3·0189	3·0081	2·9974	2·9867	2·9760	2·9652	2·9545	2·9438	2·9330
113	2·9223	2·9120	2·9017	2·8913	2·8810	2·8707	2·8604	2·8501	2·8397	2·8294
114	2·8191	2·8092	2·7992	2·7893	2·7794	2·7695	2·7595	2·7496	2·7397	2·7297
115	2·7198	2·7102	2·7007	2·6916	2·6816	2·6721	2·6625	2·6530	2·6435	2·6339
116	2·6244	2·6152	2·6059	2·5967	2·5874	2·5782	2·5689	2·5597	2·5504	2·5412
117	2·5319	2·5230	2·5141	2·5052	2·4963	2·4874	2·4785	2·4696	2·4607	2·4518
118	2·4429	2·4343	2·4257	2·4171	2·4085	2·3999	2·3913	2·3827	2·3741	2·3655
119	2·3570	2·3486	2·3403	2·3320	2·3237	2·3154	2·3071	2·2988	2·2905	2·2822
120	2·2739	2·2659	2·2578	2·2498	2·2418	2·2338	2·2257	2·2177	2·2097	2·2016
121	2·1936	2·1858	2·1781	2·1703	2·1625	2·1548	2·1470	2·1392	2·1314	2·1237
122	2·1159	2·1084	2·1008	2·0933	2·0858	2·0783	2·0707	2·0632	2·0557	2·0481
123	2·0406	2·0333	2·0260	2·0188	2·0115	2·0042	1·9969	1·9896	1·9824	1·9751
124	1·9678	1·9607	1·9537	1·9466	1·9396	1·9325	1·9254	1·9184	1·9113	1·9043
125	1·8972	1·8903	1·8834	1·8766	1·8697	1·8629	1·8561	1·8492	1·8424	1·8355
126	1·8287	1·8221	1·8154	1·8088	1·8022	1·7956	1·7889	1·7823	1·7757	1·7690
127	1·7625	1·7560	1·7496	1·7432	1·7367	1·7303	1·7239	1·7174	1·7110	1·7045
128	1·6981	1·6919	1·6856	1·6794	1·6731	1·6669	1·6606	1·6544	1·6481	1·6419

TABLE III.—(*Continued.*)

v.	0	1	2	3	4	5	6	7	8	9
f.s.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.	degs.
129	1·6356	1·6295	1·6234	1·6174	1·6113	1·6052	1·5991	1·5931	1·5870	1·5810
130	1·5749	1·5689	1·5630	1·5571	1·5512	1·5453	1·5394	1·5334	1·5275	1·5216
131	1·5157	1·5099	1·5042	1·4984	1·4927	1·4870	1·4813	1·4756	1·4698	1·4641
132	1·4584	1·4528	1·4472	1·4417	1·4361	1·4305	1·4249	1·4193	1·4138	1·4082
133	1·4026	1·3972	1·3918	1·3863	1.3809	1·3755	1·3701	1·3646	1·3592	1·3538
134	1·3484	1·3431	1·3378	1·3325	1·3272	1·3220	1·3167	1·3114	1·3061	1·3008
135	1·2955	1·2904	1·2852	1·2801	1·2749	1·2698	1·2646	1·2595	1·2543	1·2492
136	1·2440	1·2390	1·2340	1·2289	1·2239	1·2189	1·2139	1·2089	1·2038	1·1988
137	1·1938	1·1889	1·1840	1·1791	1·1742	1·1693	1·1644	1·1595	1·1546	1·1497
138	1·1448	1·1400	1·1352	1·1305	1·1257	1·1209	1·1161	1·1113	1·1066	1·1018
139	1·0970	1·0923	1·0876	1·0829	1·0783	1·0736	1·0689	1·0643	1·0596	1·0549
140	1·0503	1·0457	1·0412	1·0366	1·0321	1·0275	1·0229	1·0184	1·0138	1·0093
141	1·0047	1·0002	·9958	·9913	·9869	·9824	·9779	·9735	·9690	·9646
142	·9601	·9557	·9514	·9470	·9427	·9383	·9339	·9296	·9252	·9209
143	·9165	·9122	·9079	·9036	·8994	·8951	·8908	·8866	·8823	·8780
144	·8737	·8695	·8653	·8612	·8570	·8528	·8486	·8444	·8402	·8361
145	·8319	·8278	·8237	·8196	·8155	·8114	·8073	·8032	·7991	·7950
146	·7910	·7870	·7830	·7790	·7750	·7710	·7669	·7629	·7589	·7549
147	·7509	·7470	·7430	·7391	·7350	·7312	·7273	·7234	·7194	·7155
148	·7115	·7077	·7038	·6999	·6961	·6922	·6884	·6845	·6806	·6768
149	·6729	·6691	·6654	·6616	·6578	·6540	·6502	·6465	·6427	·6389
150	·6351	·6314	·6277	·6239	·6202	·6165	·6128	·6091	·6053	·6016
151	·5979	·5943	·5906	·5870	·5833	·5797	·5760	·5724	·5687	·5651
152	·5614	·5578	·5542	·5506	·5470	·5435	·5399	·5363	·5327	·5291
153	·5255	·5220	·5185	·5149	·5114	·5079	·5044	·5009	·4973	·4938
154	·4903	·4868	·4834	·4799	·4765	·4730	·4695	·4661	·4626	·4592
155	·4557	·4523	·4489	·4455	·4421	·4387	·4352	·4318	·4284	·4250
156	·4216	·4183	·4149	·4116	·4082	·4049	·4015	·3982	·3948	·3915
157	·3881	·3848	·4815	·3782	·3749	·3716	·3684	·3651	·3618	·3585
158	·3552	·3520	·3487	·3455	·3422	·3390	·3357	·3325	·3292	·3260
159	·3227	·3195	·3163	·3132	·3100	·3068	·3036	·3004	·2973	·2941
160	·2909	·2877	·2846	·2814	·2783	·2751	·2719	·2688	·2656	·2625
161	·2593	·2562	·2531	·2500	·2469	·2439	·2408	·2377	·2346	·2315
162	·2284	·2254	·2223	·2193	·2162	·2132	·2102	·2071	·2041	·2010
163	·1980	·1950	·1920	·1890	·1860	·1831	·1801	·1771	·1741	·1711
164	·1681	·1652	·1622	·1593	·1563	·1534	·1505	·1475	·1446	·1416
165	·1387	·1358	·1329	·1300	·1271	·1243	·1214	·1185	·1156	·1127
166	·1098	·1070	·1042	·1013	·0985	·0957	·0929	·0900	·0872	·0844
167	·0816	·0788	·0760	·0732	·0705	·0677	·0649	·0621	·0594	·0566
168	·0538	·0511	·0484	·0456	·0429	·0402	·0375	·0347	·0320	·0293
169	·0266	·0239	·0213	·0186	·0159	·0133	·0106	·0080	·0053	·0027

The notation of Table III. and the method of using it is similar to that of Tables I. and II., explained in Chap. V. (p. 246).

Practical examples.

EXAMPLE (1).—What is the range and time of flight of a 12-lb. shot fired with a muzzle velocity of 1680 f.s. at 3° of quadrant elevation; the jump being taken at 20′, and the diameter of the shot 3 ins.?

Here angle of departure, α, $= 3° 20'$,

$$\frac{d^2}{w} = \tfrac{3}{4}.$$

The whole ascending branch of the trajectory may be taken, and at the vertex

$$\beta = 0;$$

hence $$D = \alpha - \beta = 3° 20'.$$

In applying the formula for small angles of departure,

$$D_{q \sec \bar{\phi}} = D_{p \sec \bar{\phi}} + \frac{d^2}{w} D \sec \bar{\phi}.$$

sec $\bar{\phi}$ may be neglected, and p sec $\bar{\phi}$ may be taken equal to V, the muzzle velocity, and q sec $\bar{\phi} = v$, the remaining velocity at the end of the arc under consideration; so that the above formula becomes

$$D_v = D_V + \frac{d^2}{w} D = D_{1680} + \tfrac{3}{4} \times 3{\cdot}333$$
$$= {\cdot}0538 + 2{\cdot}5 = 2{\cdot}5538;$$
$$\text{or } v = 1168.$$

The formula for computing $\bar{\phi}$ is in this case, where $\beta = 0$,

$$\bar{\phi} = \frac{\alpha}{2} + \frac{p - q}{p + q} \frac{\alpha}{3};$$

and since $p = V$ and $q = v$ nearly,

$$\bar{\phi} = 1° 40' + \frac{1680 - 1168}{1680 + 1168} \times \frac{300'}{3} = 1° 40' + 12' = 1° 52'.$$

The formula for computing X is

$$\frac{d^2}{w} X = \cos \bar{\phi} \, (S_{q \sec \bar{\phi}} - S_{p \sec \bar{\phi}});$$

which may be written in this case

$$\frac{d^2}{w} X = \cos \bar{\phi} \, (S_v - S_V);$$

$$\text{or } X = \frac{4 \times \cos 1° 52'}{3} (S_{1168} - S_{1680}) \qquad \text{since } S_{1168} = 2665$$
$$S_{1680} = \underline{\quad 83}$$
$$= 3443 \cos 1° 52' \qquad\qquad 2582$$
$$= 3441 \text{ ft.}$$

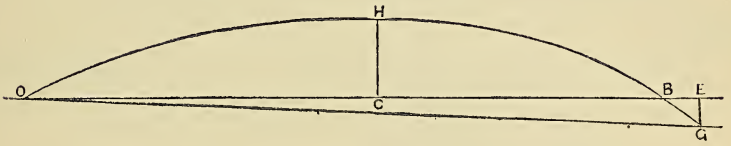
Similarly,

$$Y = \cdot 3443 \sin 1^\circ\ 52'$$
$$= 112 \cdot 2 \text{ ft.}$$

Similarly,

$$T = \tfrac{4}{3}\,(T_{1168} - T_{1680})$$
$$= 2 \cdot 48 \text{ secs.}$$

since $T_{1168} = 1 \cdot 9081$
$T_{1680} = \cdot 0493$
$1 \cdot 8588$



To explain: the arc OH (where H is the vertex of the trajectory) has been computed, and

$$OC = X = 3441 \text{ ft.},$$
$$HC = Y = 112 \text{ ft.},$$

or the height which the shot would have to fall from the vertex to reach a horizontal line through the muzzle of the gun. But if the range is measured to a lower level, G, the distance EG must be added to the height the shot has to fall—suppose in this case 15 ft.; then the height the shot has to fall from the vertex is $112 + 15 = 127$ ft.

In computing the descending branch, it is necessary to decide upon some angle at the end of the arc and as near as possible to the actual angle of descent. In this case compute the descending branch from 0° to 5°.

Then, proceeding as before, since $D = 5^\circ$,

$$D_v = D_v + \frac{d^2}{w}\,D = D_{1168} + \tfrac{3}{4} \times 5 = 6 \cdot 3\,; \quad \text{since } D_{1168} = 2 \cdot 550 + 3 \cdot 75 = 6 \cdot 300$$
$$\therefore\ v' = 953 \cdot 5 \text{ f.s.},$$

and

$$\bar{\varphi}' = 2^\circ\ 30' - \frac{1168 - 953}{1168 + 953} \times \frac{300'}{3}$$
$$= 2^\circ\ 30' - 10' = 2^\circ\ 20';$$

then

$$X' = \tfrac{4}{3} \cos 2^\circ\ 20'\ (S_{953 \cdot 5} - S_{1168}) \quad \text{since } S_{953 \cdot 5} = 4853,\ S_{1168} = 2665,\ 2188,\ 4,\ 3)8752,\ 2917$$
$$= 2917 \cos 2^\circ\ 20' = 2914 \text{ ft.},$$
$$Y' = 2917 \sin 2^\circ\ 20' = 119 \text{ ft. nearly.}$$

i.e., there is yet $127 - 119$ ft. $= 8$ ft. to fall.

The little extra distance due to a fall of 8 ft. may be approximated to by

$$X'' = 8 \cot 5° = 8 \times 11{\cdot}43 = 91{\cdot}4 \text{ ft.}$$

Now,

$$\begin{aligned} X &= 3441 \\ X' &= 2914 \\ X'' &= 91 \end{aligned}$$

or total range = 6446 ft. = 2148·6 yds.

Again,

$$T' = \tfrac{4}{3}\,(T_{953{\cdot}5} - T_{1168})$$

$$= 2{\cdot}81 \text{ secs.}$$

$$\begin{aligned} T_{953{\cdot}5} &= 4{\cdot}0137 \\ T_{1168} &= 1{\cdot}9081 \\ & \overline{2{\cdot}1056} \\ & 4 \\ & \overline{3)8{\cdot}4224} \\ & \overline{2{\cdot}8074} \end{aligned}$$

The little extra time taken to travel over $X'' = 91$ ft. may be approximated to by dividing the distance by the velocity at end of the arc of 5°—*i.e.*, by $v' = 953$ f.s.; or

$$T'' = \frac{91}{953} = {\cdot}095.$$

Now,

$$\begin{aligned} T &= 2{\cdot}48 \\ T' &= 2{\cdot}81 \\ T'' &= {\cdot}09 \end{aligned}$$

or total time of flight = 5·38 secs.

In practice with this gun at Shoeburyness under similar conditions, the mean range of 10 rounds was found to be 2128 yds.—the maximum being 2161 yds. and the minimum 2097. The mean time of flight was observed to be 5·5 secs.

An example of the approximate solution of high-angle trajectories will now be given.

Example (2).—The 8-in. M.L. howitzer is fired at an angle of quadrant elevation of 30°, and jumps 1°. What will be the range and time of flight? Muzzle velocity = 745 f.s., weight of shell = 180 lbs., diameter of shell = 7·92 ins.

The most correct way of solution would be to divide the ascending branch into three or more component arcs, and compute over each arc; and in the same way with the descending branch. But this would

make the calculation too long for ordinary purposes. The ascending branch will be computed in one step.

Here $$\alpha = 31°,\ \beta = 0,\ D = 31°,$$

$$\log \frac{d^2}{w} = 9{\cdot}5422,\ V = 745,$$

$$\tan \bar{\phi}_1 = \frac{\tan 31°}{2} = \frac{{\cdot}60086}{2} = {\cdot}30043;$$

$$\therefore\ \bar{\phi}_1 = 16° 43',$$

$$\text{and } p \sec \bar{\phi}_1 = 745 \cos 31° \sec 16° 43' = 667 \text{ f.s.},$$

$$\text{also } p = 638{\cdot}6.$$

$q \sec \bar{\phi}_1$ may be found by substituting in equation (i.) [note],

$$\left(\frac{1000}{q \sec \bar{\phi}_1}\right)^3 = \frac{\frac{d^2}{w} \times 31 \times \sec 16° 43'}{9{\cdot}54655} + \left(\frac{1000}{667}\right)^3$$

$$= 1{\cdot}182 + 3{\cdot}370 = 4{\cdot}552,$$

$$\text{and } q \sec \bar{\phi}_1 = 603{\cdot}4 \text{ f.s.};$$

$$\text{or } q = 577{\cdot}8.$$

The correct value of $\bar{\phi}$, then, is

$$\bar{\phi} = \bar{\phi}_1 + \frac{p - q}{p + q} \cdot \frac{\alpha}{3}$$

$$= 16° 43' + \frac{639 - 578}{639 + 578} \times \frac{31 \times 60}{3}$$

$$= 16° 43' + \frac{61 \times 620}{1217} = 16° 43' + 31' = 17° 14',$$

$$\frac{d^2}{w} X = \cos \bar{\phi} \left(S_{q \sec \bar{\phi}} - S_{p \sec \bar{\phi}}\right)$$

$$= \cos 17° 14' \left(S_{603{\cdot}4} - S_{667}\right);$$

$$S_{603{\cdot}4} = 14282$$
$$S_{667} = 11828$$
$$2454$$

$$\text{or } X = 6726 \text{ ft.},$$

$$Y = X \tan 17° 14' = 2086 \text{ ft.},$$

$$T = \frac{w}{d^2}\left(T_{603{\cdot}4} - T_{667}\right)$$

$$= 11{\cdot}06 \text{ secs.}$$

$$T_{603{\cdot}4} = 16{\cdot}777$$
$$T_{667} = 12{\cdot}904$$
$$3{\cdot}873$$

N.B.—As Table III. is not calculated below 900 f.s., it becomes necessary to make the calculation independently.

$$\frac{d^2}{w} D \sec \bar{\phi}_1 = D_{q \sec \bar{\phi}_1} - D_{p \sec \bar{\phi}_1} = \frac{180g}{\pi} \cdot \frac{(1000)^3}{64{\cdot}4} \int_{q \sec \bar{\phi}_1}^{p \sec \bar{\phi}_1} \frac{dv}{v^4}$$

(since $K = 64{\cdot}4$, and is *supposed* constant below 900 f.s.)

$$= \frac{180 \times 32{\cdot}2}{3\pi} \times \frac{1}{64{\cdot}4} \left\{\left(\frac{1000}{q \sec \bar{\phi}_1}\right)^3 - \left(\frac{1000}{p \sec \bar{\phi}_1}\right)^3\right\}$$

$$= 9{\cdot}54655 \times \left\{\left(\frac{1000}{q \sec \bar{\phi}_1}\right)^3 - \left(\frac{1000}{p \sec \bar{\phi}_1}\right)^3\right\};$$

$$\text{or } \left(\frac{1000}{q \sec \bar{\phi}_1}\right)^3 = \frac{\frac{d^2}{w} D \sec \bar{\phi}_1}{9{\cdot}54655} + \left(\frac{1000}{p \sec \bar{\phi}_1}\right)^3. \quad \text{.....(i.)}$$

In the descending branch, compute from 0 to 34·2°; then

$$\beta = 34{\cdot}2^\circ,\ D = 34{\cdot}2^\circ,$$

$$\tan \bar{\varphi}_1 = \frac{\tan 34^\circ\ 12'}{2} = {\cdot}3398\,;$$

$$\text{or } \bar{\varphi}_1 = 18^\circ\ 46',$$

$$p = 577{\cdot}8, \text{ and } p \sec \bar{\varphi}_1 = 610{\cdot}3,$$

$$\left(\frac{1000}{q \sec \bar{\varphi}_1}\right)^3 = \frac{\frac{d^2}{w} \times 34{\cdot}2 \times \sec 18^\circ\ 46'}{9{\cdot}5466} + \left(\frac{1000}{610{\cdot}3}\right)^3$$

$$= 1{\cdot}319 + 4{\cdot}400 = 5{\cdot}719,$$

$$\text{or } q \sec \bar{\varphi}_1 = 559{\cdot}2 \text{ f.s., and } q = 529{\cdot}5\,;$$

$$\text{then } \bar{\varphi} = 18^\circ\ 46' - \frac{578 - 530}{578 + 530} \times \frac{34^\circ\ 12'}{3}$$

$$= 18^\circ\ 46' - 30' = 18^\circ\ 16',$$

$$\frac{d^2}{w} X' = \cos 18^\circ\ 16' \left(S_{559{\cdot}2} - S_{610{\cdot}3}\right);$$

$$\begin{aligned} S_{559{\cdot}2} &= 16316 \\ S_{610{\cdot}3} &= 13991 \\ &\overline{2325} \end{aligned}$$

$$\text{or } X' = 6334 \text{ ft.},$$

$$Y' = X' \tan 18^\circ\ 16' = 2091 \text{ ft.},$$

$$T' = \frac{w}{d^2}\left(T_{559{\cdot}2} - T_{610{\cdot}3}\right) = 3{\cdot}984 \times \frac{w}{d^2}$$

$$\begin{aligned} T_{559{\cdot}2} &= 20{\cdot}281 \\ T_{610{\cdot}3} &= 16{\cdot}297 \\ &\overline{3{\cdot}984} \end{aligned}$$

$$= 11{\cdot}43 \text{ secs.},$$

$$\text{range} = X + X' = 6726 + 6334$$

$$= 13060 \text{ ft.}$$

$$= 4353 \text{ yds.},$$

$$\text{time of flight} = T + T' = 11{\cdot}06 + 11{\cdot}43 = 22{\cdot}49 \text{ secs.},$$

$$\text{and } Y - Y' = 2086 - 2091 = -5 \text{ ft.}$$

or the projectile strikes 5 ft. below the horizontal line.

From above,

$$q = 529{\cdot}5,$$

so that

$$\text{striking velocity} = 529{\cdot}5 \sec 34^\circ\ 12' = 640{\cdot}3 \text{ f.s.}$$

The same example worked out more carefully by Bashforth's method of solution gives

$$\text{range} = 13197 \text{ ft.} = 4399 \text{ yds.}$$

$$\text{time of flight} = 22{\cdot}87 \text{ secs.}$$

$$\text{and striking velocity} = 635 \text{ f.s.}$$

When the experiments for determining the coefficients for velocities below 900 f.s. are completed, and Tables I., II., and III. extended in accordance with the results observed, the solution of high-angle trajectories will be approached with greater confidence.

(To be continued.)

RESULTS OF EXPERIMENTS

MADE IN THE

ROYAL CARRIAGE DEPARTMENT

(July 1877)

TO ASCERTAIN THE RELATIVE VALUE, IN POINT OF TRACTION, OF THE SERVICE, OR SERVICE-MODIFIED, AND THE MADRAS FIELD WHEELS AND AXLES.

COMMUNICATED BY

MAJOR W. KEMMIS, R.A.

With regard to traction, the value of any particular wheel and axle depends upon the amount of ease with which they permit of the carriage they belong to being drawn over any ground, and upon the distance which they will travel without heating.

When comparison is made between wheels and axles of the same diameters and width of tire, and equally well lubricated, any difference of ease in traction will be due mainly to difference in weight of the wheels and in the amount of their cone. The resistance due to the latter, it is hardly necessary to say, is greater as the conical form is more developed, and may be considered constant in amount in any particular wheel. This amount varies directly with the width of the tire, and inversely with the diameter, and in the field wheel is not very great. The resistance due to weight is, in the field wheel, of more importance, because it increases directly with the unevenness or inclination of the ground; as is readily understood when we consider that the weight of the wheels, as well as of the carriage body and load, has to be lifted over every obstacle or incline which may oppose their motion. This resistance—which would be diminished to *nil* on a perfectly hard, smooth, and level road—is always of some amount, as in reality there is no such thing as a road of the nature mentioned.

With regard to the distance which wheels will travel without heating—the dimensions, material, and clearance of their axles, the means of protection against grit and the lubricant being the same—it will depend mainly upon the amount of the latter which can be stored up in the pipe-box, and the rate at which it is expended due to the relative form of construction of the wheel and axle, which may or may not give a tendency, as the wheel revolves, to the grease to flow out or to be absorbed from undue local pressure and consequent tendency to heat at a particular spot.

In the comparative trial made, the experiments, upon the above considerations, were arranged as follows:—

I. *To test Traction.*—The carriages (limbers) to which the wheels

were fitted were loaded, to give in each the same weight upon the wheels (7 cwt. 1 qr. 21 lbs.), attached, in succession, to a dynamometer, fitted to a limber, and carefully drawn at a speed of three miles an hour over the same ground. The dynamometer used is one of very simple construction, designed by Mr. Butter, Manager R.C.D., in which the variation of draught is registered, by a pencil attached to the spring of the draught-hook, upon a graduated paper wound round a metal cylinder, which latter revolves as the limber is moved forward.

II. *To test Lubrication.*—The carriages to which the wheels were fitted were firmly fixed, in succession, in such a manner that one wheel was driven by a wooden friction pulley made to revolve at a given rate by steam shafting; the pulley was arranged to press against the wheel with a greater force than the wheel with its maximum load would, in ordinary use, bear against the ground, while its speed was such as to make the wheel revolve at the rate of 20 miles an hour. The latter was thus made to travel under similar, but more severe conditions, to what it would if running on a smooth hard road; while the absence of minor disturbances inseparable from a road—such as constant varying inequalities, dust, &c.—rendered the comparative trial strictly accurate. Before starting, each wheel was lubricated with the same quantity of the service grease, and arrangement provided for catching any that escaped during travelling. The latter quantity and the remain was measured on the conclusion of the trial.

The wheels and axles experimented upon were—

A. The service field wheel and axle of latest pattern (9 or 16-pr.) —namely, diameter of wheel, 5 ft.; width of tire, 3 ins.; dish of spokes, 2 ins.; strut, or inclination outwards of working spoke, *nil*; pipe-box of phosphor bronze, grooved, with recess for $6\frac{1}{4}$ ozs. of grease; centre of pressure in pipe-box, $5\frac{1}{4}$ ins. from face, and $4\frac{3}{4}$ ins. from back; line of pressure (wheels level) coincident with central line of working spoke; hollow, or downward inclination of under side of axle-arm, ·4 in. in 10 ins.; weight of wheel, 2 cwt. 1 qr. 2 lbs.

B. A proposed modification of the service field wheel and axle, differing from them in the following particulars:—Strut of working spoke, $\frac{3}{4}$ in.; an additional grease chamber, formed in the outer flange, giving a capacity, with the ordinary recess, for 13 ozs. of grease, and admitting of the wheel being greased without removal from its axle; centre of pressure in pipe-box, $4\frac{1}{2}$ ins. from face, $5\frac{1}{2}$ ins. from back; line of pressure (wheels level) nearly coincident with central line of working spoke; hollow, ·15 in. in 10 ins.; weight of wheel, 1 cwt. 3 qrs. $9\frac{1}{2}$ lbs.

C. The Madras wheel and axle, differing from the service (*A*) as follows:—Strut, 2 ins.; centre of pressure, $3\frac{1}{8}$ ins. from face of pipe-box, and $6\frac{7}{8}$ ins. from back; line of pressure (wheels level) falling out of the working spoke, crossing its face at the edge of the front flange; hollow, *nil*, but an upward inclination of the under side of the arm of ·36 in. in 10 ins.; weight of wheel, 2 cwt. 1 qr. $6\frac{1}{2}$ lbs.

The relative advantages and disadvantages of the foregoing wheels and axles may briefly be summed up as follows:—In *A*, there not being any strut to the working spoke, the cone of the wheel is a maximum, while in *C* it is a minimum, or *nil;* giving the latter, therefore, the advantage in ease of draught in this respect. Apart, however, from draught, such a large amount of strut is disadvantageous; causing, as we have seen, the line of pressure to cross the spoke when in its normal position, and so giving a tendency to break it, and also, for a given track, reducing the width between the wheels at the axle (in *A* this distance is 4 ft. 1½ ins., in *C* 3 ft. 9 ins.), which curtails the room for axle-seats in the gun-carriage, and for ammunition boxes—and therefore ammunition—in the wagon and limbers.

In *A* and *B* the centre of pressure corresponds with, or approximates to, the centre of the pipe-box, but in *C* it does not; so that in the latter a cross action of the wheel upon its arm is produced, causing greater friction and tendency to heat at certain points, more particularly at the base of the arm on the upper side—being the furthest bearing from the centre. In this respect, therefore, the construction of the Madras wheel is contrary to all principle and radically defective.

The wheel *B*, it will be noticed, is a medium, as regards strut, between *A* and *C*; that is to say, as much strut is given in it to the working spoke (being advantageous in assisting the spoke when the wheels are not on the level, and in reducing the amount of cone necessary for the wheel) as can be given without prejudice, namely, in reducing the distance between the wheels, in misplacing the line of pressure, or in sloping the under side of the axle-arm the wrong way. The additional grease chamber, as already pointed out, is an advantage in giving more space for grease, and permitting the wheel to be greased without removal; but in addition to this, as in the service wheel the grease always works towards the shoulder, it supplies the lubricant at the correct spot. The weight of *B* is also in its favour, not only, as already stated, on account of traction, but also in opposing less inertia to recoil in the gun-carriage, and therefore putting less strain upon the axletree.

I.—*Results of Experiments on Traction.*

Nature of ground.	Tractive force in lbs.					
	Mean.			Maximum.		
	A	*B*	*C*	*A*	*B*	*C*
Asphalt road, level, smooth	Not tried.	26	34	Not tried.	70	97
Do. inclined 1½° to 2°, smooth		104	111		145	150
Do.,do., with obstacles 1 in. high, at regular intervals		107*	113*		166	180
Road of ashes, level, fairly smooth		76	87		143	200

* The mean tractive force required to surmount the obstacles was respectively 138 and 142 lbs.

In the foregoing table we see the results, as anticipated, wholly in favour of the modified service wheel and axle.

II.—*Results of Experiments on Lubrication.*

Nature of wheel and axle.	Amount, in ozs., of grease expended.					Heating, &c.
	On completing 80 miles.				On completing 160 miles.	
	Run out at face.	Run out at back.	Used.	Total spent.	Total spent.	
A	·25	·80	1·25	2·30	3·50	Nave and arm cool throughout.
B	·25	·50	·50	1·25	2·25	Nave and arm cool through first 80 miles, slightly warm through second 80, but not increasing.
C	2·50	·50	1·50	4·50	—	Heated gradually, till towards close of first 80 miles so hot that the grease burnt, and the running had to be discontinued.

Examining the above table, we see the results are in favour of the modified service wheel and axle, in addition to which it is to be remembered that this wheel has capacity for 13 ozs., while the others can hold but $6\frac{1}{4}$ ozs. The latter amount was put in each wheel previous to starting, in *A* and *C* in the grease recess, and in *B* in the additional chamber in the flange, without removing it from the axle-arm.

From this experiment we may fairly conclude that the service field wheel of the latest pattern—apart from any question of further improvement—is a satisfactory wheel, and not liable to fire, if only reasonable attention be given to its lubrication.

September, 1877.

HISTORICAL NOTICES OF THE ROYAL ARTILLERY.

[No. III.]

BY

MAJOR F DUNCAN, L.L.D., &c.,

Royal Artillery.

The accompanying extract from the Records of the East Kent Militia possesses considerable interest to the Royal Artilleryman. The order appeared in the same month as that in which the 8th Battalion was formed: it contains the arguments used at the time for an augmentation of the corps, for it shows that an infantry regiment of militia was being employed in the capacity of gunners: it was issued by a General, famous both in life and in death, Sir John Moore; and it reveals the expectation of imminent invasion which prevailed during a critical year in England.

Nor is the order without humorous features. The modern reader may well smile at the pompous prophecies of a French Army baffled on its landing by finding an enemy satisfied with a few yards' start in retreating, and proudly conscious that "it is the last shot that tells." And there is a delicious sarcasm in the sentence which reminds the brave amateurs that careless and premature firing encourages an opponent,—a sarcasm which doubtless secretes between the lines records of some loose gun-practice which had come under the observation of the gallant General.

But humorous or pompous, it was expressive of an earnest feeling in England. In this very year the English Ambassador had been insulted in the Tuileries: and English blood—plebeian or patrican—boiled at the insult. Against the expected invasion,—the blow thought certain to follow the word,—the gallant East Kent were arrayed as auxiliaries to the Royal Artillery, and as such received high commendation.

There is a purpose in cherishing these old traditions. There is no greater folly than in deliberately forgetting them.

EXTRACT FROM REGIMENTAL RECORDS.

EAST KENT REGIMENT OF MILITIA.

Marched to Dungeness, 8th July, 1803. 2 *Companies detached to Forts Moncrieff and Sutherland, near Hythe.*

Inspected by General Moore, 28th September, 1803.

GENERAL MOORE'S INSTRUCTION TO THE EAST KENT MILITIA.

General Orders for Officers Commanding Forts.

"The Forts under your command and in which your Regiment is stationed, "I mean those of Dungeness, are not such as can make much resistance "against a land attack. If the enemy had landed in force, it would be your "duty to retire, destroying the gun carriages, and ammunition, with the "implements provided for that purpose. As sea batteries, however, they are "formidable, and if the guns are well served, and the previous disposition "and arrangements are made with judgment, it will be impossible for an "enemy to disembark within their reach. Every attention must be paid to "make the men expert at the exercise of the great guns. They must be "exercised twice a-day until perfect, and then always once a-day, lest they "should forget it. Captain Smith has directions to visit you frequently to "judge of your progress, and he will issue a proportion of ammunition for "practice, when he thinks the men sufficiently forward. At these visitations "you will point out to him whatever deficiencies have been observed in guns, "platforms, &c., and if they are very important you will also report them to "me, that they may be remedied. It is of importance to you that every part "of the Batteries be in good order, as your character, and that of the Officers "and men under you is materially interested in the defence you are able to "make. You should direct a disposition to be made at each Fort for the de-"fence of the Post, and you cannot be too explicit to your Officers and men "with respect to the conduct you expect from them in case of an attack. "The alarm post of every Officer and man should be ascertained, the manner "explained in which they are to turn out upon any alarm, the persons named "who are to deliver on such an occasion the small arms, ammunition, what "men are to man the guns, which to keep their muskets, the places where "the muskets and packs of the men at the guns are to be placed that they "may have resource to them if ordered: in short everything, however "minute, which you think can occur, should have its previous instruction, "that noise and confusion may be avoided in the moment of danger. The "ammunition to complete your men to 2 flints and 60 rounds should be put "in the possession of the Officers at the different Forts, who will keep it in "the magazine of the Fort in which they are stationed, at their own disposal "ready to deliver to the men when required. The proportion of camp ket-"tles, bat horses, and other parts of camp equipage which have been issued "should also be with the different companies, in charge of their respective "Captains or Commanding Officers, so that when your companies meet, each "may come with what belongs to them. The bat horses, women, &c., should "be sent to the rear in case of attack. The signal of alarm is a smoke by "day, a fire by night from the beacon fixed some hundred yards to your right "as you look at the signal-post on Lymne Height, or from the beacon fixed "on Shorncliffe Height, near the redoubt. Your sentries should have orders "to observe these, though in all probability, from the officer at your own "signal-post at Dungeness you will have the first notice of the approach of an "enemy. Every intelligence of the approach of an enemy of which you "have reason to think me ignorant, you will dispatch to me by a Dragoon to "Sandgate, and to the Officer Commanding at Rye, and you will of course, "at the same time warn the Volunteers and Sea Fencibles at Lydd and New "Romney. You will of course complete the companies in Forts Moncrieff "and Sutherland with ammunition &c., the same as those at Dungeness. If "you have any for practice you will do well to divide it amongst the com-

"panies, with directions to them to use it for their instruction. The officers "and men cannot be too much warned against throwing away their fire by "beginning too soon when the enemy is at a distance, or by firing carelessly "without taking pains to lay their guns. This sort of fire, instead of in- "juring, encourages an enemy; it is when within the reach of grape that "your fire will have the greatest effect, and it is only after having got very "close to you that a brave enemy will be defeated. The Officers and men of "the East Kent will, I trust, recollect this, and not think of abandoning "their guns, or of retiring until absolutely forced. It is better to risk being "taken than to abandon too soon, for it is the last shots which tell; at all "events it is of importance to show the French what they are to expect in "their invasion of England; after that there may still be time to retreat; a "few yards start is sufficient, as an enemy is always cautious of following in "a country he does not know."

Note.—The East Kent Militia was stationed at Woolwich Garrison (during one of the embodiments) from August 3rd 1854, to April 5th, 1855, when it marched to Portsmouth and embarked for Malta, where it remained till 4th June, 1856. Such was the good conduct and high state of discipline maintained by the regiment, that the Commandant at Woolwich specially requested that the East Kent Militia might be again stationed there on return from Malta; and the regiment was quartered at Woolwich for the second time from November 16th, 1857, to June 15th, 1858.

ROCKET SHELLS, AND ARTILLERY OF THE FUTURE.

BY

LIEUT. E. N. HENRIQUES, R.A.

Having frequently heard thoughtful artillerists regret the withdrawal of rockets from field and siege service generally,* I have been led to consider the defects which caused them to be so far given up, and to enquire whether the rocket principle can be retained with such modifications as will render it an useful adjunct in modern warfare.

The undoubted end of all military engagements is to break down as rapidly as possible the moral force of the enemy.

However great the carnage and destruction of *matériel*, as long as the survivors have the *morale* or resolution to stand their ground, the fight remains undecided.

This is the hinge on which alone the fate of battles depends, but which is so often disregarded by military writers in estimating the value of projectiles by their physical effects alone—thus mistaking one of the means for breaking the resolution of the enemy and putting him to flight as the one end of artillery fire.

If, then, there be other means to be added—more rapid, simple, and certain than slaughter pure and simple—by which the moral force which makes a man stand up and face danger in the field of battle, rather than follow his natural instincts and fly from it, can be broken down, it will be an advantage of the most solid kind to the army employing them. The art of destruction has already been carried to a very high pitch of excellence, to the partial neglect of other influences; and I believe that a great deal may yet be done to increase the effect of modern arms of precision by directing attention to the other means by which the *morale* of armies is destroyed.

Against these views it can no doubt be urged with truth, "He that fights and runs away, lives to fight another day." This drawback is, however, more apparent than real, and there will be found to exist advantages which, when the balance is struck, will far outweigh it.

The losses suffered by opposing armies on the field of battle are usually pretty nearly even during the main part of an engagement, and it is principally in the retreat of a defeated army that it suffers large disproportionate losses from an active pursuit which renders its defeat decisive and crushing. It therefore appears that the losses in actual battle array are of minor importance to putting the enemy as rapidly as possible to flight, and pressing him hotly by a vigorous pursuit. The material gain to the victor will then be increased; the less *matériel* is

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* See "Army Equipment Regulations," 1876, par. 112. "War rockets will not form any portion of the equipment of fortresses; they will only be employed with siege trains and in the field, as occasions and circumstances demand."

destroyed, the fewer men are killed, and the fresher he is for carrying out his pursuit. All serviceable *matériel* falling into his hands is a double advantage to him, as it not only destroys the enemy's force but transfers it undiminished to his opponent; and as to men, for every one *hors de combat* on the one side there is a corresponding proportion on the other, varying approximately between 100 and 75 per cent., whereas large captures in retreat are effected with comparatively small losses. The guarding and marching to the rear prisoners of war can, as a rule, be safely executed by small forces of inferior troops, which may be diminished the further the prisoners are removed.

These are, then, the advantages I conceive to belong to the destruction of moral force as rapidly as possible; and it is only by due consideration and development of all the agents at work on the battle field that the result can be obtained. Physical destruction, no doubt, stands out among the other agents; but it is by no means alone in the field.

Now, the real advantages claimed for rockets are of this nature:— Their direct physical effects are but small at the best of times, yet the moral effect they produce by the volume of flame they pour out, their hissing noise, &c., is considerable, especially when they can be directed on troops suddenly and with some degree of precision. On the other hand, when occasionally they hit their mark, the force of impact is very trifling; they have no bursting arrangement, and even their power of setting fire to buildings is uncertain.*

The special defects which have opposed the employment of rockets as warlike projectiles may thus be summarised:—

1. The difficulty of laying them properly.†
2. Irregularities in flight (lateral).
3. Uncertainty of range.
4. Height of trajectory.
5. Low velocity at long ranges.
6. Small momentum after bursting.
7. Great weight of each round.
8. Considerable deflections after graze.

In the construction of the rocket shell I have endeavoured to lessen or to obviate these evils, to increase as far as possible the special qualities of rockets in their moral effects, and at the same time not to lose sight of the more common qualities in material destruction.

The reader will have observed in the above list of defects that none of them can fairly be attributed to projectiles fired from modern rifled ordnance, except perhaps No. 8, and that only in a very small degree.

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* Sir Samuel Baker observes that rockets pass through native huts constructed of reeds without firing them; and this was also my experience in the Perak expedition, Malay Peninsula, 1875-6.

† Defects in the trough have been pointed out in the reports of Major Rait and Lieut. Knox on the ammunition used in the expedition to Commassie. I would also observe that the elevating bar is graduated on the supposition that the trough is resting on a level plane. In hill and jungle warfare, for which Hale's war rocket is admirably adapted, it is therefore generally impossible to lay the trough accurately without spirit-level and quadrant. At short ranges I have therefore invariably laid my rockets by eye, and made in this way very fair practice indeed in the Malay native states.

We thus arrive at the primary idea of firing a rocket from a rifled gun, and this is the general outline of the manner in which I would apply it :—

The figure represents an iron shell with studs, filled with rocket composition, and hollowed out inside, as in the ordinary rocket, with this difference: the coned hollow penetrates to the head of the projectile, so causing very rapid combustion. There are three vents in the base, closed by rivet-shaped plugs fitting easily, and a steel plate over the vents, closed round the edges with lead, hammered or cast in between it and the base of the shell. The usual "half-shields" of rockets will, I imagine, be found superfluous. The difficulty of ensuring the three vents being blown out simultaneously, at first suggested having one vent in the centre of the base; but I do not think this would answer, as the equilibrium of forces acting on the shell, when burning, would not be so well established, and the flight would therefore be more irregular.

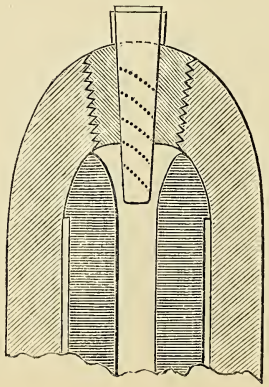
The shell should be increased in length to make up the weight to that of the ordinary shell for the particular gun, and to enable the ordinary service charge to be used.

Sufficient rocket composition to burn from 3 to 5 secs. will answer all requirements.

As regards the head of the rocket shell, two plans suggest themselves :—(1) to have a solid plug screwed in over the fuze; (2) to have a fourth vent in the head. Having gained all the advantages of a flat trajectory, it may possibly be found useful, once the projectile has reached the zone in which it is intended to act, to reduce its velocity to some extent, or even to delay it as long as possible while burning. It is difficult from theory alone to determine the precise merits of these alternative plans. Possibly they may both be found useful, and then it would be left to the battery commanders in the field to decide, according to requirements, whether solid or hollow plugs should be used.

While wavering between these different plans, the time fuze question must be considered for each particular case.

First, suppose shells with head-vents to be alone employed. The head-vent must be restricted to a certain size (to be determined by experiment), in order to ensure sufficient internal pressure to blow off the vents and base plate. The ordinary R.M.L. fuze (9 secs.) will



therefore probably be too thick to be inserted in the ordinary way, and it would occupy too much internal space if wholly inside with a hollow cylinder screwed over it; hence a smaller fuze (perhaps of metal) must be used, which will be blown out on ignition of the rocket composition. (See figure.)

Now suppose shells without head-vents are alone to be employed; then some fuze like the Armstrong *E* time must be used. The solid plug closing the head of the shell might form also the head of the fuze (as in figure).

Thirdly, suppose it is advisable to fire on both plans; then the last fuze would be used in the one case, and in the other the same fuze with a hollow cylindrical head, through which certain parts of the fuze would be blown, on ignition of the rocket, and afterwards it would act as a vent. (See figure.)

The same embarrassment does not, however, occur with the percussion fuze; the momentum of the rocket shell being equal to that of the ordinary projectile, a fuze on the plan of the "B.L. plain percussion" will probably be found to answer very well, with a hollow or solid plug screwed over it. With the head-vent, some portions of the fuze must be made so that the ignition of the shell will blow them out.

To complete the shell, I would propose to have a layer of gun-cotton (in suitable form) between the rocket composition and the walls of the shell; or, if that is not possible, the gun-cotton might be arranged in grooves in the metal of the shell, which would also facilitate the breaking up of the shell on explosion.

This development of my idea is necessarily very defective, and artillerists of practical experience in the construction of ammunition will no doubt be able to make many material changes for the better, should the principle of rocket shells be considered worth a trial.

In fine, a word on the action and application of the proposed shell.

The rocket shell being fired with service charge from a rifled gun, proceeds with all the accuracy of the ordinary projectile until the fuze ignites the composition. Gas will now be rapidly generated, and the internal pressure will increase until the base plugs, acting upon the base plate, force it off. Our rocket shell will now proceed with accelerated velocity (supposing no head-vent) and with volumes of fire issuing from its base. It will resemble the ordinary war rocket, but with these differences: that instead of soaring up into the air and coming down at a very high angle, with low velocity and small momentum, a flat trajectory will carry it near the ground, and there will be no loss of momentum or variation in the position of the centre of gravity from the burning of the composition till the shell comes within its sphere of action.

To ensure all the moral effects of the shell, it should be ignited some 200 or 400 yds. in front of the enemy's line by means of a time fuze. Against *solid* buildings to be fired and destroyed, a percussion fuze will be found more useful.

When employing the head-vent, more flame will be generated before the base-vents are opened, the flame will escape more rapidly, and the

burning will be quicker; the velocity will be reduced, and the flight will be to some extent more irregular. In field service, once the shell has reached its zone of action, these qualities will, I believe, increase its effects; and finally the gun-cotton will explode the shell amongst the reserves and supports in rear, if the fuze is adjusted to allow for the burning of the composition.

It is not to be expected that the bursting of this shell will be so effective as even a common shell, because of the violent action of gun-cotton; and from the want of some transmitting medium, it will not break up into as many pieces as it would with gunpowder.*

It is against cavalry, however, that I believe this shell will be most effective. Infantry with a good cause and by a good training, &c., can be brought into action with a very large amount of moral resolution, which will enable it to bear up against the greatest odds and the most trying conditions. With the cavalry soldier it is, however, different; the stability of cavalry depends on the horse as much as the man. The horse is essentially a timid animal, and, however well trained, is more inclined, as a rule, to fly from danger than his rider. In fact, of all arms cavalry is the one to which moral force is of the greatest importance. Therein lies its strength as much as its weakness. Once fear or panic seizes any portion of a body of horse, disorder soon follows amongst the whole, and it becomes not only useless in itself but an embarrassment to the other troops. Here, then, we have an object particularly vulnerable to the forces of moral disorganisation, and on which, therefore, the rocket shell would have the best chance of success. Besides this, the power of cavalry of manœuvring in front of an enemy renders it a very transitory mark for artillery fire, and the better it is handled the shorter will be these intervals of exposure. Now, if during these periods—which are often too short for common and shrapnel shell to take effect, supposing even that the varying ranges can be accurately estimated—rocket shells were employed, if there be any value in them at all, their results would be perceived almost instantaneously. Squadrons that would face with equanimity a salvo or two of rocket shells, well directed, would not, I imagine, be much embarrassed by any number of such fireworks.

It is here to be remarked that the same accuracy of fire is not needed with the rocket shell as with others to reap its full *moral* effects; hence the same deliberation to discover the ranges will not be required.

Carcass shells might also be constructed something after this pattern.

RANGOON,

October, 1877.

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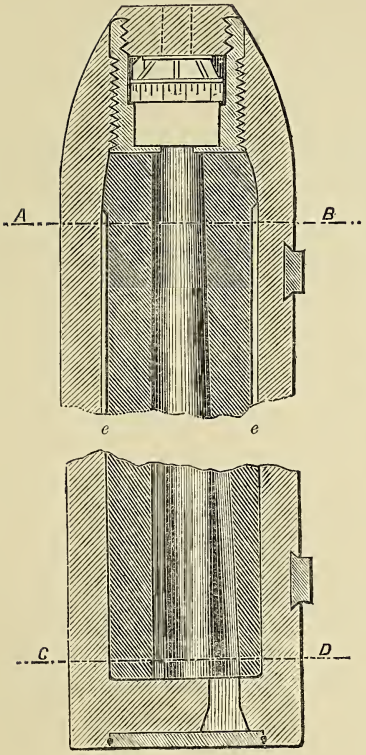
* It is stated in "Treatise on Ammunition," 1874, p. 205, that the 16-pr. common shell with 1 oz. of gun-cotton, and filled of course with water, burst into 262 pieces.

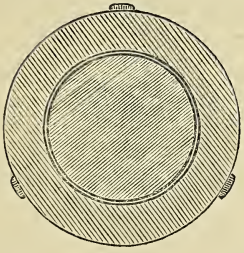
ROCKET SHELL FOR 16-PR. M.L.R.

(Scale $\frac{1}{3}$.)

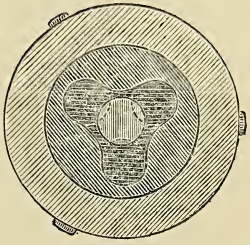


The gun-cotton, represented by white space, *ee*, next to the metal of the shell, does not extend to that portion of the shell where the composition is not symmetrically in the axis and the hollow circular; so that it will not explode till all the composition is burned.

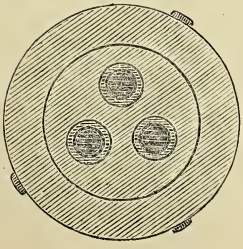
Base.



Section *CD*.



Steel base plate removed.



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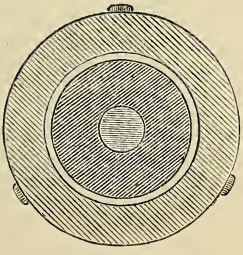

TRANSLATION FROM THE FRENCH CONCERNING A NEW FORM OF CARRIAGE FOR FIELD ORDNANCE FIRING HEAVY CHARGES, WITH ITS APPLICATION TO PROPOSED FIELD GUNS FOR OUR OWN SERVICE.

BY

LIEUT. GOOLD-ADAMS, R.A.

TRANSLATOR'S NOTE.

AT a time when we are about to re-arm our field artillery with new and far more powerful weapons, it is hoped that the account of an apparently successful attempt to devise some form of carriage which shall be light, yet strong enough to bear heavy charges, will be read with interest.

Whether this plan possesses all the advantages claimed for it can only be decided by experiment.

NEW FIELD CARRIAGE (IRON) FOR LONG-RANGE GUNS.

BY

COLONEL ENGELHARDT,

OF THE

RUSSIAN ARTILLERY OF THE GUARD.

At the present time it is regarded as a necessity throughout the whole of Europe to adopt long-range guns, fired with a high charge. The production of the guns does not present any very great difficulty: the whole question consists of the choice of the material to be employed, and this has been decided differently in different states. In England, the field guns are made of iron (the bore being strengthened by a steel tube); Prussia makes them of steel; Sweden of cast-iron; in France, Switzerland, Italy, Austria, and Russia the field guns are of bronze, and cast hollow by the four latter powers. Moreover, lately in Austria and Russia the strength of the bore has been increased by the compression of its walls.

The guns themselves, amongst all the different powers, have not given rise to serious difficulties; the same cannot be said with regard to the carriages of most European states. Everywhere we find the recoil to be very severe, in spite of their weight—already too great.

The design and construction of field carriages for long-range guns presents some very great difficulties; because they must satisfy two principal, and at the same time contradictory, conditions.

The carriage must, in the first place, be sufficiently strong; in the second place, it must be light, and give a moderate recoil. But the action of a gun on its carriage results in a shock, and it is well known that the resistance of a body to shock is proportional to its section. Thus, to satisfy the first condition we must make the carriage heavy, contrary to the requirements of the second; the effects of firing, on the other hand, being more destructive to the carriage as it is heavier.

Heavy guns strain their carriages less than light, when they both fire projectiles of the same weight under the same conditions.

Thus, on account of the adoption of long-range guns, we have been led, in order to save the carriages, to give to the gun itself a greater weight than the strength of the material composing it demands. Moreover, to secure sufficient strength in the carriages, we have given to their various parts greater dimensions. The total weight has thus been again increased, so that everywhere for long-range guns the system (gun and carriage) reaches a very considerable weight, as can be seen by the following table:—

Country.	Metal of carriage.	Weight.				Muzzle velocity of shell.
		Projectile.	Gun.	Carriage.	System.	
		lbs.	cwt.	cwt.	cwt.	f.s.
England	Iron	16	12	12	24	1350
France	"	23·76	13·75	12·84	26·59	1452
		15·4	12	13·7	25·7	1280
		11·2	9	10·2	20·2	1370
Prussia	Steel	15·4	9	10·3	19·3	1460
Austria	Steel & iron	14	9·6	10·3	19·9	1485
Sweden	Iron	8·58	7·4	9·3	16·7	1280
Switzerland ...	"	12·1	8·53	9·2	17·73	1200
Italy	"	8·8	6	8	14	1320
Russia	"	24·2	12·2	9·6	21·8	1200
		12·54	6·43	9·6	16·03	1404

It follows from this table that, except in Russia, the weight of carriages intended for guns firing high charges, whose muzzle velocities exceed 1250 f.s. and the weight of whose projectiles is more than 8·8 lbs., varies between 10·2 and 13·7 cwts., and the system between 20 and 26·5 cwts. These are very considerable weights, when we

consider the great mobility demanded of field artillery of the present day.

Hitherto, there has been no generally received method of determining with exactness the destructive effects of a gun upon its carriage when fired; but mechanics teaches us that when a sudden blow is imparted, a part of the work is used up in displacing the particles of the body.

The action of a gun on its carriage, as we saw above, partaking of the nature of a blow, a part of the work must be absorbed by displacing the molecules of the trunnions and of the carriage, and if we can evaluate that loss of work we should have an approximate idea of the action of the gun on its carriage.

We have, then,

m = the weight of the projectile,
β = " " charge,
v = muzzle velocity of projectile,
m' = weight of gun,
m'' = " carriage,
v' = velocity of recoil of gun at first moment,
v'' = " " system (maximum).

We have, then, the following equation—

$$\left(m + \frac{\beta}{2}\right) v = m'v'.$$

Therefore

$$v' = \frac{\left(m + \frac{\beta}{2}\right) v}{m'}.$$

The work done in recoil by the gun is expressed by

$$\frac{m'v'^2}{2} = \frac{m'}{2} \frac{\left(m + \frac{\beta}{2}\right)^2 v^2}{m'^2} = \frac{\frac{1}{2}\left(m + \frac{\beta}{2}\right)^2 v^2}{m'}.$$

The velocity of recoil of the system is found by

$$(m' + m'')\, v'' = m'v' = \left(m + \frac{\beta}{2}\right) v.$$

Therefore

$$v'' = \frac{\left(m + \frac{\beta}{2}\right) v}{m' + m''}.$$

The stored-up work of system may be expressed

$$\frac{(m' + m'')\, v''^2}{2} = \tfrac{1}{2}\,(m' + m'') \frac{\left(m + \frac{\beta}{2}\right)^2 v^2}{(m' + m'')^2} = \frac{\frac{1}{2}\left(m + \frac{\beta}{2}\right)^2 v^2}{m' + m''}.$$

The difference between the energy of recoil of the gun at the moment of discharge, and that of the system after that instant, expresses the quantity of work absorbed by the displacement of the particles of the trunnions and of the carriage. The difference is—

$$\frac{\frac{1}{2}\left(m+\frac{\beta}{2}\right)^2 v^2}{m'} - \frac{\frac{1}{2}\left(m+\frac{\beta}{2}\right)^2 v^2}{m'+m''} = \frac{1}{2}\left(m+\frac{\beta}{2}\right)^2 v^2 \left(\frac{1}{m'} - \frac{1}{m'+m''}\right)$$

$$= \frac{1}{2}\left(m+\frac{\beta}{2}\right)^2 v^2 \frac{m''}{m'(m'+m'')} = A. \quad \ldots\ldots\ldots\ldots (1)$$

Let $$\frac{m'}{m''} = n = \frac{\text{weight of gun}}{\text{weight of carriage}},$$

(1) becomes $$A = \frac{\frac{1}{2}\left(m+\frac{\beta}{2}\right)^2 v^2}{(n+1)\,m'}.$$

This last formula shows that with the same muzzle velocity the difference, A (work done on carriage), is less as the value of n increases; that is to say, the work done on the carriage is less as the relation of the weight of the gun to the weight of the carriage increases.

We can, as an application of this formula, by means of the numerical data given above, form a table of values of A for most of the field carriages used, and we then find that the carriage for the 9^c Prussian gun is that which is strained most. The proportion of the weight of the gun to that of the carriage is all to the disadvantage of the latter; but nevertheless it stands the trial in a satisfactory manner, although relatively lighter than the other carriages. Its strength results from the substitution of steel for iron, the resistance within the limits of elasticity of the first-named being much greater than that of the latter. But steel, in spite of its precious qualities, is a very uncertain metal, the application of which in the construction of carriages has not yet been completely worked out, and upon which it is difficult to rely.*

We can give as proof the following facts:—

In Prussia, various parts have been broken on several occasions; in Austria, one of the four steel carriages furnished by Krupp has had its trail broken. We must observe also that the 9^c Prussian gun upon its carriage weighs 19·3 cwt.—that is to say, 4 cwt. more than the ordinary Russian 4-pr. on its carriage.

We thus see that the method of construction of existing carriages furnishes us with no data for the construction of a carriage at the same time light and fit for long-range guns; so that to solve the problem we are led to study a system of carriage entirely new, of which we are about to try to explain the chief peculiarities. We shall give later on a detailed description of its construction.

In order to design a carriage, we must, first of all, make a compara-

* The writer, of course, speaks of Russia, where this difficulty is probably a very real one.—Tr.

tive study of the different parts of those already existing. To facilitate this, a table, C,* has been formed, showing the principal dimensions of carriages, both Russian and foreign.

This table shows that all the new carriages are sensibly shorter than ours.

Because, then, it is possible to construct a new carriage shorter than the present ones, we can profit by this fact to lessen the weight thereby.

We can also make a reduction of weight by replacing the angle-irons by a flange bent over on the brackets of the trail itself—a method which ensures sufficient strength in the brackets in a much more certain way than the employment of angle-irons. Brackets thus constructed cannot in reality be made of metal of bad quality, because good iron alone can stand the test of manufacture; and as they are formed of one single piece, they offer greater certainty of the necessary solidity than do those into whose construction angle-irons enter. With these latter, one has always to fear the flying out of one or two rivets, which at once lessens the strength. This accident cannot happen with bent-over brackets.

The only inconvenience which these latter present consists in the difficulty of procuring them. In Prussia, all the carriages are made in the State arsenals, and the brackets are furnished by Krupp, who makes a great secret of his method of compressing the steel for them. In Austria, they have had to give up the employment of bent-over brackets, on account of difficulties of manufacture. In Russia, the solution of this question has also presented some very great difficulties; but, thanks to the activity of the Golonbieff factory, we have succeeded in preparing the formers, and in discovering the qualities of iron capable of being subjected to the process; so that the question of bending over the edges of iron brackets may be regarded at the present time as being finally settled in Russia.

We must also direct our attention to the means of securing the rigid connection of the brackets to each other.

In the present Russian carriages this connection is obtained by means of tie-bolts furnished with nuts. This method of connection gives truly the possibility of rapidly taking the carriages to pieces, but presents also, precisely for this reason, a great inconvenience; in travelling, the nuts, &c., shake loose, from the jolting, so that the two brackets do not always form parts of a rigid system. This could not happen if they were united by transoms.

Thus, in the new carriage, the connection is not only made by collar bolts but also by transoms. These latter are placed obliquely with regard to the edges of the brackets, in place of being normal to them, as in the carriages of the other powers. This disposition still further strengthens the connection, the obliquity of the transoms opposing all lateral bending of the carriage.

To avoid excessive weight in the construction of the new carriage, the brackets are made to converge towards their end. This permits of

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* It has not been considered worth while to insert this table. It would only be practically useful to a manufacturer. The reader is referred to "Revue d'Artillerie" of August 1877.—TR.

replacing the large transom of the ordinary trail by a narrow trail end, embracing above and below the brackets, of which it strengthens the connection at this point in a most efficient way. It prevents one of the brackets only being subjected to any shock whatever; it transmits it to both at once.

These different improvements increase the intrinsic strength of the carriage, but in no way modify the effects of the gun upon it. The intensity of these effects, as we have seen above, can be expressed by

$$\frac{\frac{1}{2}\left(m + \frac{\beta}{2}\right)^2 v^2}{(n+1)\,m'},$$

and depend on the magnitude of n—that is to say, on the relation between the weight of the gun and that of the carriage.

Consequently, in order to obtain a sensible diminution of the destructive effects of the gun on the carriage, it will be necessary to reduce largely the weight of the latter; but as the gun-carriage is at the same time a travelling carriage, into the construction of which there enter wheels, axletree, and seats, the weight of which we cannot lessen, it becomes practically impossible to lighten the carriage. We can, however, lessen the destructive effects of the gun if we divide the carriage into two distinct parts—the carriage properly so called as one part, and the axletree, with wheels and seats, as the other.

This division is effected in the following way. The axletree, in place of being housed in the brackets, can slide backwards and forwards within the straps which unite it to them. At the inner ends of the axletree-arms it is held by two tie-bars, which are united to each other at their other ends by a collar-bolt, square in section. In the same way as the axletree, this collar-bolt can move in a slot cut for this purpose in the brackets. The collar-bolt, tie-bars, and axletree form thus a frame upon which are fixed the axletree-seats. This frame placed upon wheels constitutes one part of the carriage.

This part is connected with the trail by means of two bolts with pierced heads, *hh* (see Plate, Figs. 2 and 3), fixed to the square collar-bolt, *ff*. These bolts pass through the transom, *cc*, and the iron plate, *gg*, between which are placed several thicknesses of cork. The cork is now replaced by india-rubber, which is more durable. This modification is applied to carriages of recent construction. The threaded ends of the bolts, *hh*, are furnished with screwed nuts, whose play compresses the india-rubber and exercises a force on the collar-bolt, *ff*, and consequently on the axletree, towards the transom, *cc*. The axletree is thus pulled back until it takes a bearing against the rear side of the straps which unite it to the bracket.

The layers of india-rubber interposed form an elastic buffer, the thickness of which is reduced from 7·1 ins. to 3·59 ins. by the screwing up of the nuts. It is then under a pressure of about 4 tons 16 cwt., as we can see from the following table, which shows the thickness of the buffer under various pressures, measured from direct experiment, the section of the buffer being about 45 sq. ins.

Pressure.			Thickness.	Compression.
tons	cwt.	qrs.	ins.	ins.
0	0	0	7·1	Nil
1	6	0	4·4	2·7
3	16	3	3·84	3·26
5	1	0	3·4	3·7
6	8	2	3·2	3·9
8	2	2	2·7	4·4
9	19	0	2·48	4·62
13	10	0	2·12	4·98
17	12	0	1·98	5·02
20	1	0	1·92	5·08
23	10	0	1·84	5·26
30	0	0	1·78	5·32
72	5	0	1·64	5·46

The weight of the first* of the parts into which the carriage is, so to speak, divided, is reduced to 3·8 cwt. It is this part, then, that on discharge receives the blow of the gun; then, when its own inertia is overcome, the motion is imparted to the second part by the intermediate action of the buffer, which, when firing the 9-pr. gun, with a muzzle velocity of 1200 f.s., suffers a compression of 1·52 ins. Table B (in which is given the work absorbed by the old and new carriage) shows that, when firing the ordinary 9-pr., the work absorbed is only 1754 ft. lbs. by the first part (trail, &c.,) of the new carriage, while it rises to 3783 ft. lbs. in the old. When firing the long range 9-pr. with a muzzle velocity of 1200 f.s., the new carriage still only absorbs 3529 ft. lbs., as the table also shows; from which we may conclude generally that the new carriage suffers much less than the old.

To try to determine the work done by the compression of the buffer, we must remember that before discharge it is supporting a pressure of 96 cwt., as we saw above. On firing, it is further compressed 1·52 ins.—that is to say, its thickness is reduced from 3·56 ins. to 2·04 ins.; and the foregoing table shows that this thickness corresponds to a pressure of 13 tons 14 cwt. 3 qrs. nearly, which represents the greatest pull exercised, on discharge, by the buffer bolts.

The work realised by the resistance of the buffer to this compression

$$= \text{mean pressure} \times \text{compression}$$

$$= \left(\frac{96 + 274{\cdot}5}{2}\right) 112 \text{ lbs.} \times \frac{1{\cdot}52}{12} \text{ ft.} = 2600 \text{ ft. lbs.}$$

Table B shows that the carriage without a buffer absorbs 6000 ft. lbs. (about), while the carriage with a buffer only absorbs 3329 ft. lbs.; that is to say, 2470 ft. lbs. less—a difference practically equal to the resistance of the buffer, which, as we saw above, is 2600 ft. lbs. If it did not exist, the tie-bars and brackets must absorb this amount of work; but, thanks to the compression of the buffer, the destructive effects are very greatly reduced. Without it, these parts would be subjected to a strain very much too great; the brackets suffering by compression, and the tie-bars by tension.

* This part is of course the brackets of the trail, &c.—Tr.

The correctness of these considerations is fully proved by experience. The first carriage for the long-range 9-pr. was made without a buffer, upon the type of the Swiss carriage, and was furnished with a cylindrical axletree 3·3 ins. in diameter, securely fixed by three straps to the brackets and to its middle point. At the end of 30 rounds fired with the 9-pr. the axletree broke, and was replaced by one still more solid, the body of which was square in section, of 4·04-in. side. This new axletree broke also after 10 rounds with the 9-pr. with a charge of 5·4 lbs. The carriage was then mounted on the ordinary field axletree strengthened by tie-bars, but it broke at the end of 250 rounds; the rupture probably taking place from the bad quality of the iron. When the broken axletree was removed, it was discovered that all the bolt-holes connecting it with the carriage, had worked oval, and that all the bolts themselves were twisted and sheared.

After this accident a buffer was fitted, and thus modified the carriage stood, without the least damage, 604 rounds from the ordinary 9-pr. and the heavy 4-pr., of which 80 were fired with the trail sunk in the ground, so as to stop all recoil. At the end of the firing, the trail was buried almost up to the elevating gear.

On this model a new carriage was made, which stood without damage 1190 rounds from the long-range 4-pr. After this first trial, the axletree was replaced by a stronger one, in order to be strong enough for the 9-pr. The carriage with axletree thus strengthened received then a long-range 9-pr., with a chamber enlarged, in order to obtain a muzzle velocity of 1200 f.s. With this gun, 404 rounds were fired with a charge of 5·63 lbs. of large-grain powder, of which 100 rounds were at 20°. The carriage stood this trial without damage.

Two seats were then fitted, also fixed on buffers of india-rubber. Before this modification the seats had begun, at the end of 200 rounds, to show such damage that at the end of the trials of the carriage, they were nearly entirely detached. The seats fixed on buffers are not exposed to this danger.

With the third carriage, 1600 rounds were fired with the long-range 4-pr. The carriage, &c., stood this trial without damage. The excess of strength thus shown in the carriage allowed of a further improvement—viz., of fitting across the end of the trail a square plate, which fixes itself in the ground (see sketch), for the purpose of checking the recoil. This modification reduced, as a general rule, the sum of recoils of 20 rounds to 7 paces; that is to say, that at the end of 20 rounds, the recoil had only driven the gun back 7 paces from the spot it occupied before firing. This diminution of the extent of the recoil has the great advantage of facilitating and accelerating the working of the gun.

The trial endured with the 9-pr., with a velocity of 1200 f.s., showed that that velocity could be increased still more, as also could that of the light 4-pr.

We find in Table B that the velocity of recoil of the system is 18 ft. per second for the long-range 9-pr. with a velocity of 1200 f.s., while it is only 17·3 f.s. for the light 4-pr. with a velocity of 1404 f.s.; while the 9-pr. weighs 12·2 cwt., and the light 4-pr. only weighs 6·43 cwt.

The action of the 9-pr. on the buffer is, then, much more severe than that of the 4-pr. We can see by Table B that the ordinary 9-pr. even trys its carriage more than the 4-pr. Experience, moreover, confirms these deductions: when firing the long-range 9-pr., the buffer is compressed 1·52 ins., while the compression only reaches ·76 in. in the case of the light 4-pr. Thanks to the favourable results thus attained, we are enabled to go from the service guns to guns of long range without increasing the weight of the system, as the following figures show:—

Gun.		Weight.		
		Gun.	Carriage.	System.
		cwt.	cwt.	cwt.
9-pr.	Service	12	10·3	22·3
	Long range	12·2	9·6	21·8
4-pr.	Service	6·43	9·2	15·63
	Long range	6·43	9·6	16·03

It follows, then, from what we have said, that the division of the carriage into two distinct parts, and the adoption of a buffer, leads to a system entirely different to that adopted as yet by any power. This system gives the following advantages over those existing at present, viz.:—

1. It makes it possible to construct for long-range guns, and without increase of weight, carriages sufficiently strong with iron as a material. This metal gives every safety in its use.*

2. It is not necessary to increase the weight of the guns, although heavier charges are fired.

3. The recoil can be reduced to almost nothing, and even be entirely stopped if necessary.

4. Finally, we can employ one carriage for all the field artillery, whether old or new.

Description of the Carriage. (See Plate.)

The new iron field carriage is intended to take not only the 9-pr. and 4-pr. guns actually in the service, but also those of the same calibre and long range recently experimented upon. It is composed of two parts—the body of the carriage and the transporting part of it—united in such a manner that the blow impressed on the first part by the trunnions of the gun is only progressively communicated to the other part by the intermediate action of an elastic buffer.

The body of the carriage is formed of two brackets of plate iron, about ·25 in. thick, with the edges turned over round the whole cir-

* This, of course, allows of a still greater improvement in carriages if steel be used.—Tr.

cumference. The flanges thus formed round the brackets replace the angle-irons employed to strengthen the existing carriages.

The brackets are united by four transoms (*a*, *b*, *c*, *d*), two collar-bolts, through which pass two bolts, *m* and *n*, and a trail-eye-piece, *p*. They form a converging trail, their dimensions decreasing progressively towards the trail end; their outside depth being 14·6 ins. (about) at the trunnion holes, and 7·5 ins. at the end of the trail. Towards the breast of the carriage the trunnion-holes are strengthened by bands underneath, and closed by hinged cap-squares.

The first transom is placed following the line *aa*, going obliquely from the trunnion holes to the axletree, on meeting which it bends and follows the lower edge of the brackets for a length of about 8 ins. Its upper part is hollowed out to receive the gun.

The second transom is also placed obliquely following the line *bb*, starting from the rear extremity of the trunnion-hole bands and stopping at the lower edge of the brackets; it also is hollowed out for the same purpose as the first transom, to which it is nearly parallel. On the lower surface is placed a plate of sheet-iron, so as to form a sort of box.

The third and fourth transoms follow the lines *ee*, *dd*, and serve also as transverse walls of a trail-box. The two first and the last transoms, (*aa*, *bb*, *dd*) are riveted by their edges to the brackets; the third differs—the lower edge alone is bent at right angles, the other edges of it are riveted to the bent edges of two strengthening plates, which, on the inside of the brackets, reinforce the sliding seat of the movable bolt, and the upper edge to a plate connecting the brackets at the top, near the elevating gear. This latter plate is cut out in front to allow room for the elevating gear, and its three other sides have their edges bent downwards, the long sides over the brackets and the rear side against the transom to which it is riveted. The connection between the brackets is, moreover, assured by two collar-bolts and a trail-piece. One of these collar-bolts, *m*, is placed near the elevating gear and the other near the trail-piece, where it also serves to secure the front ends of the handles. The trail-piece is of iron plate, about ·25 in. thick, and riveted to the bent edges of the brackets; its lower part—prolonged towards the axletree to replace the usual transom—has an opening in which is fixed a bronze trail-eye, the lower face of which is rounded off, so as to facilitate limbering-up.

The bottom of the trail-box, formed by the two lower transoms and the brackets, is formed of an iron plate fitted to the lower bent edges of the transoms, and riveted with them to the brackets; the lid is also formed of plate-iron, of which the long sides are bent over the brackets, while the short sides carry the hinges and the iron flaps necessary for opening and shutting the box, in which is placed the india-rubber buffer.

The elevating gear is a double screw, similar to that in the service. The nut is not fixed on a special support, but is furnished with trunnions which rest on two bearings, *q*, of elliptical form riveted to the brackets.

The right trunnion is pierced with a threaded hole, in which works a screw, having on the outside of the bracket a handle attached to it, *e*; the other end rests against a piece of steel (*s*, Fig. 7) with threads corresponding to those of the nut, and movable in a bearing in the

latter, of which it forms part of the wall. One can, then, with the handle press this piece of steel against the outside screw of the elevating gear and prevent it from turning. The elevating screw has a ratchet head and collar revolving freely. The handle has a tooth which gears in the teeth of the ratchet.

The head of the inner screw is fastened by a bolt to a movable fork, of which the arms are, at their other end, each hinged.

These latter are fixed to the front transom.

The handspike folds back on to the trail. It is composed of a wooden lever, held between the jaws of an iron shoe which takes the form of an arc near its point of attachment. In action, the handspike is placed between two projections, *v v*, fixed above the trail-piece, and in which it is held by the pawl with which it is furnished. When not in use, the handspike folds back on the lid of the trail-box, in a support furnished with a hinged flap.

The trail has two handles, to enable it to be raised and lowered, and in order to diminish the recoil as much as possible, it terminates in a steel cross-plate, solidly fastened, which by cutting a hole in the ground reduces the recoil to about 7 ins. on firm ground.

The carriage also has the usual fittings for drag-shoes, spade, gun-bucket, and case shot.*

The above is the first part of the carriage.

The second part of the carriage is composed of the axletree, its seats, the tie-bars, movable collar-bolt, and the buffer.

The axletree rests in iron straps, each fixed to a strengthening band underneath the brackets by two bolts. The straps, with the strengthening bands, form rectangular seats in which the axletree can slide backwards or forwards, as their breadth is greater than its greatest thickness.

The axletree is of iron, and at the shoulder is about 2·5 ins. square, while the body, properly so called, is of the same breadth, but 3·5 ins. deep.

From the shoulder of each axletree-arm goes a tie-bar, *b*, which reaches the middle of the trail, where it ends by an eye, which receives one of the ends of the movable collar-bolt. This latter passes through two slots cut for it in the brackets, and furnished on the outside with parallel guide-cheeks. This arrangement is made to maintain constant, in every position of the system, the distance between the interior faces of the ends of the tie-bars. The play allowed between the guide straps and body of the axletree is exactly the same as between the movable collar-bolt and the ends of the slots cut for it in the brackets.

The axletree, tie-bars, and movable collar-bolt thus form a trapezoidal frame capable of receiving a certain amount of motion backwards and forwards with reference to the trail. Between the ends of the tie-bars and the guide-cheeks on the trail there are placed on the collar-bolt alternate rings of copper and iron, to lessen the lateral blows which in firing may be accidentally caused.

The movable collar-bolt passes through the holes in the heads of the

* The underside of the carriage is arranged to carry 1 case shot for the 9-pr. and 2 for the 4-pr.

two bolts, *h h*, which pass through the third transom and also through an iron plate. Between these latter is placed the buffer, composed of 7 plates of cork (or india-rubber) between 2 plates of oak. Nuts, screwed on to the ends of the bolts which pass through the iron plate, cause, by compressing the buffer, a pull on the frame towards the transom. At rest, the axletree and movable collar-bolt should both lie, for this reason, against the rear end of their seats. To prevent the nuts unscrewing, they are fixed by a double iron key, which does not allow them to turn, and is held in its place by a peg fixed in the compression plate.

The cork, before being used for the buffer, ought first to be boiled in a mixture of three parts (by volume) of water and one of honey, then submitted to a pressure sufficient to reduce its thickness 20 per cent. and then coated with soap.* To make the buffer, there are placed three times in succession two thicknesses of pressed cork and one plate of iron, and then a seventh thickness of cork; further, it is necessary that the iron plates should overlap the edges of the cork about ·1 in., so that pieces of the latter should not become detached. The buffer thus formed has a thickness of about 7·1 ins. between the plates; the pressure of the compressing screws brings this down to from 3·35 ins. to 3·55 ins. Now the buffer is ready to act.

In firing, it is necessary to watch that the elasticity of the buffer does not diminish, and for this purpose to take note of the movement of the axletree in its guide straps. The extent of this movement should not exceed 2 ins.

The wheels of this carriage are of the old pattern; but the nave has been a little shortened, and has been furnished with a cylindrical pipe-box which projects slightly beyond it, and is arranged so as to give a close fit at the end of the axletree-arm.

The axletree and the tie-bars serve as supports for two seats for gunners, and are provided with hinged foot-rests. Each seat is placed on three springs formed, like the buffer, of alternate plates of cork and iron, placed in an iron cylinder. A bolt passes down the axis of the cork, and through the bottom of the cylinder.

The two front supports are fixed on the axletree, and the rear one on the tie-bar. The rear support of the off seat is ended below by a hook for the gun-bucket.

In firing, the trail begins to recoil sooner than the axletree and wheels, which only receive a shock already lessened by the compression of the buffer. At the end of the recoil, the elasticity of the buffer, which re-acts on the compression plate, causes the movable frame to come back to its first position.

Thanks to this arrangement, the axletree lasts well, and the general elasticity of the system is greatly increased. This in a very remarkable degree lessens the destructive effects of the recoil of the gun upon the carriage.

The new carriage allows of an angle of elevation of 20°.

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* At the end of a certain number of rounds (about 1000) the cork loses its elasticity. It, however, can be renewed by boiling it again in the composition. The author says that cork has been replaced by india-rubber; he does not say anything of its behaviour.—Tr.

Table A.

Table of Particulars of Guns and Carriages of Principal European Powers, with the Work done by each on its Carriage.

Country.	Gun.	Calibre.	Weight.					Velocity.			Energy of recoil.		
			Charge.	Shell.	Gun.	Carriage.	System.	Shell.	Gun.	System.	Gun.	System.	Difference.*
			lbs.	lbs.	cwt.	cwt.	cwt.	f.s.	f.s.	f.s.	ft. lb.	ft.lb.	ft. lb.
England	16-pr.	3·6	3·0	16	12	12	24	1350	17·5	8·75	6426	3200	3226
	12-pr.	3·0	...	12	7	10·5	17·5	1600	27	10·8	9125	3648	5480†
	15-pr.	3·0	...	15	7	10·5	17·5	1550	29	13	13600	5280	8320†
	9-pr.	3·0	1¾lbs.	9	6	12	18	1380	20	6·8	4250	1456	2794
Austria	8c	2·95	2·07	9·92	5·9	10	15·9	1375	23·9	8·85	5892	2183	3709
	9c	3·42	3·307	13·77	9·6	10·6	20·2	1485	23·4	11·1	9268	4374	4894
France	de 5	2·95	1·918	10·58	9	10·2	19·2	1375	16·7	7·87	4375	2067	2308
	de 7	3·34	2·49	15·43	12	13·7	25·7	1280	15·4	7·3	5061	2241	2820
	95mm	3·74	4·63	24·0	13·77	12·85	26·62	1452	23·75	12·25	13953	7085	6868
Italy ...	9c	2·95	1·2	8·763	6	8	14	1319	20	8·5	4229	1771	2458
Prussia	4c	3·09	1·10	9·37	5·7	9	14·7	1210	18·7	7·35	3506	1373	2133
	6c	3·606	1·320	13·88	8·5	10·1	18·6	1082	16·4	7·5	4084	1850	2234
	8c	3·09	2·75	11·11	7·77	9·9	17·67	1520	22·14	9·68	6507	2890	3617
	9c	3·46	3·3	15·4	9	10·6	19·6	1463	22·5	11·38	9760	4338	5422
Switzerland...	8c	3·3	2·34	12·2	8·56	9·2	17	1200	17·75	8·55	4735	2250	2485
Sweden	7c	3·011	1·719	8·57	7·38	9·2	16·58	1279	14·7	6·25	2805	1243	1562
Russia, old guns	9c	4·17	2·71	24·38	12	10·5	22·5	1060	20·4	10·69	8314	4525	3789
	4c	3·42	1·35	12·63	6·45	9·1	15·55	1000	15·9	6·35	2747	1113	1634

* This difference shows the work expended destructively on the carriage.—Tr.
† This refers to carriages without a buffer. These guns are not given in the original, but are inserted for comparison.—Tr.

Table B.

Data relative to Russian Field Guns, new and old, with regard to their effects on different pattern Carriages. Also, in comparison, Effects of English 7-cwt. new Gun as a 15-pr.

Gun.	Calibre.	Carriage.	Weight.					Velocity.			Energy of recoil.		
			Charge.	Shell.	Gun.	Carriage.	System.	Shell.	Gun.	System.	Gun.	System.	Difference.
	ins.		lbs.	lbs.	cwt.	cwt.	cwt.	f.s.	f.s.	f.s.	ft.lb.	ft.lb.	ft.lb.
Old 4-pr.	3·42	old	1·35	12·63	6·45	9·1	15·55	1000	15·9	10·69	2747	1113	1634
" "	3·42	new	1·35	12·63	6·45	3·87	10·32	1000	15·9	10	2747	1807	940
New 4-pr.	3·42	old	4·5	13·09	9·64	9	18·64	1500	20·99	10·4	7400	3651	3749
" "	3·42	new	4·5	13·09	9·64	3·87	13·51	1500	20·99	14·69	7400	5097	2303
New light 4-pr.	3·42	old	3·163	13·09	6·45	8·4	14·85	1404	27·88	12·14	8856	3839	5017
" "	3·42	new	3·163	13·09	6·45	3·87	10·32	1404	27·88	17·4	8856	5530	3326
Old 9-pr.	4·17	old	2·71	24·38	12	10·5	22·5	1060	20·4	10·69	8314	4525	3789
" "	4·17	new	2·71	24·38	12	3·87	15·87	1060	20·4	15·4	8314	6557	1757
New 9-pr.	4·17	old	5·643	24·38	12·2	10·5	22·7	1200	24	12·8	12941	6528	6413
" "	4·17	new	5·643	24·38	12·2	3·87	16·07	1200	24	18·15	12941	9348	3593
" "	4·17	new without buffr.	5·643	24·38	12·2	9·64	21·84	1200	24	13·4	12941	6911	6030
* English 15-pr.	3	old	4	15	7	10·5	17·5	1550	33	13·0	13600	5280	8320
* " "	3	new with buffer	4	15	7	4	11	1550	33	21	13600	8590	5010

* Not in original. Inserted for comparison.

(*End of Translation.*)

Results to be Obtained by the Introduction of such Carriages.

Let us now enquire what would be the theoretical gain resulting from the introduction of such carriages in our own service, in conjunction with the new experimental 7-cwt. field gun.

We suppose the gun to weigh 7 cwt., about (800 lbs.), and the whole carriage to be 10·5 cwt. (1200 lbs.), and to fire a 15-lb. shell with a muzzle velocity of 1550 f.s. A glance at the following table would show what an extremely powerful gun we should possess.

The velocities are compared with those of the present 16-pr. at similar ranges. Approximately we have

Gun.	Weight.	Charge.	Calibre.	Muzzle velocity.	Energy.
	cwt.	lbs.	ins.	f.s.	ft. tons.
16-pr. ...	12	3	3·6	1350	203
15-pr. ...	7	about 3½ to 4	3·0	1550	251

Velocities and Energy.

		Muzzle.	1000 yds.	2000 yds.	3000 yds.	4000 yds.
16-pr.	Velocity, f.s.	1350	1010	867	763	682
	Energy, ft. tons...	203	114	83	65	51
15-pr.	Velocity, f.s.	1550	1201	993	890	804
	Energy, ft. tons...	251	150	104	82·5	67

Gravity = g = 32 f.s.

On referring to table B, in which the results are obtained by the formula given above, we find that the gun has a velocity of recoil = 33 ft., and that the energy of recoil = 13,600 ft. lbs.

We also see that the energy of recoil of gun and carriage together = 5280 ft. lbs., leaving no less than (13,600 − 5280) = 8320 ft. lbs. as the work expended on the material of the carriage.

This is a much higher strain than is borne by any continental carriage, as may be seen by reference to table A.

Suppose, however, we divide the carriage into two parts, in a similar manner to that above described. The first part is supposed to weigh 4 cwt. (Russian iron one only weighs 3·87 cwt.) The total weight of gun and first part, then, = 800 + 450 = 1250 lbs.

Calculating as above, we find that the energy of recoil = 8590 ft. lbs., and that consequently only 5010 ft. lbs. are absorbed by the material of the carriage. On the ordinary form, as we saw, 8320 ft. lbs. were absorbed. Thus we have a difference in favour of the new method of 8320 − 5010 = 3310 ft. lbs.

Let us proceed, then, to calculate what work is done in compressing

the buffer, supposing it to be of the same size and description as that used in the Russian carriage, and of which the compressions and corresponding pressures are given in the table.

The Russian 9-pr., with a velocity of 1200 f.s., has an energy of recoil = 12,941 ft. lbs.; and it has been found by experiment that this energy causes a compression of 1·52 ins., reducing it from its initial thickness of 3·56 ins. to 2·04 ins.; the corresponding initial pressure being 10,800 lbs.

The compression will vary nearly as the energy of recoil; accordingly we may say that it will be about 1·6 ins., or the buffer will be reduced from 3·56 ins. to 1·96 ins. in thickness. The pressure corresponding to this latter compression = 37,200 lbs. nearly. Whence we have the following expression for work:—

$$\frac{10{,}800 + 37{,}200}{2} \times \frac{1{\cdot}6}{12} = 3200 \text{ ft. lbs.}$$

This is practically equal to the 3310 ft. lbs., which, as we saw above, is the difference between the work done on the carriage in the different systems.

Is, then, 5010 ft. lbs. too great work to put on a carriage of this weight (10·6 cwt.)? It does not appear to be so. The Russian iron carriage of 9·64 cwt. supports 3600 ft. lbs., and the German 9^{c} steel carriage of 10·6 cwt. no less than 5422 ft. lbs.

The work done on a 10·6-cwt. carriage by a 7-cwt. gun firing a 12-lb. shell with 1600 f.s., is more than 5010 ft. lbs.: it is 5480. This is, I believe, what it is intended to fire at present.

The energy of recoil of the gun = 9125 ft. lbs., and that of gun and carriage = 3645 ft. lbs., leaving 5480 ft. lbs. as the work expended.

We thus see that by means of the arrangement described in the preceding paper, we can fire a 15-lb. shell from a 7-cwt. gun with 1550 f.s. and yet strain the carriage less than we do at present. Whether the arrangement above described be open to practical objections or not is a matter for experiment; but it seems to have stood the test of many hundreds of rounds with the most satisfactory results, and fully to have attained the object with which it was designed.

We proceed now to point out what advantages may be expected from increasing the weight of shell to 15 lbs.

The following table shows the velocities of 12 and 15-lb. shells at various ranges:—

Velocity.	Muzzle.	1000 yds.	2000 yds.	3000 yds.	4000 yds.	5000 yds.
	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.
12-pr...	1600 or + 50	1166 or — 35	950 or — 43	834 or — 56	743 or — 61	671 or — 65
15-pr...	1550	1201	993	890	804	736

Thus we see that although the 15-pr. starts with 50 ft. less velocity than the 12-pr., yet it has 35 f.s. more at 1000 yds. and no less than

65 f.s. more at 5000 yds.; in fact, the 15-pr. has practically the same velocity at 5000 yds. as the 12-pr. has at 4000 yds.

Supposing, then, the total weight behind the team to be 35 cwt.—which is rather less than the present German light field gun (for horse artillery only)—we can sum up the weights as follows:

	cwt.	qrs.	lbs.	
Gun	7	0	0	
Carriage	10	2	0	
Limber	9	2	0	
Stores	1	0	0	
Ammunition	6	2	12	(40 rounds, 18·5 lbs. each.)
Total	34	2	12	

This leaves us still 44 lbs. within our limit. Fuzes and small stores would bring this up. 40 rounds is quite as much as is carried by the light guns of most other powers.

The question therefore stands thus. Is it worth while sacrificing velocity at all ranges, flatness of trajectory, shell power, and—more than all—bullet capacity, either to reduce the weight by 130 lbs. at the utmost (as each 12-pr. round will weigh 15 lbs.), or, retaining the above weight, to carry 48 rounds of 12-pr. in place of 40 15-pr.?

The answer certainly appears to be "No!"

We must remember that individual power of the guns renders their self-defensive power, and therefore their capability for more independent action, the greater; and it is only by increasing to the utmost limit this individual power that we can hope to see future artillery take that prominent position on the field of battle that all artillerymen should hope and expect it to do.

Finally, it must never be forgotten that the best guns ever issued from an arsenal are of no avail, but rather an incumbrance to the army that possesses them, unless all ranks responsible for their service are so thoroughly conversant with their use under the ever-varying conditions of warfare that it almost becomes a second nature to them. No labour or time should be grudged to attain this most essential object.

Possessing such ordnance, and with those who manœuvre and work them trained to a corresponding pitch of excellence, it is surely not too much to expect that artillery in future campaigns will accomplish results hitherto almost unthought of.

LIMERICK,

September 21, 1877.

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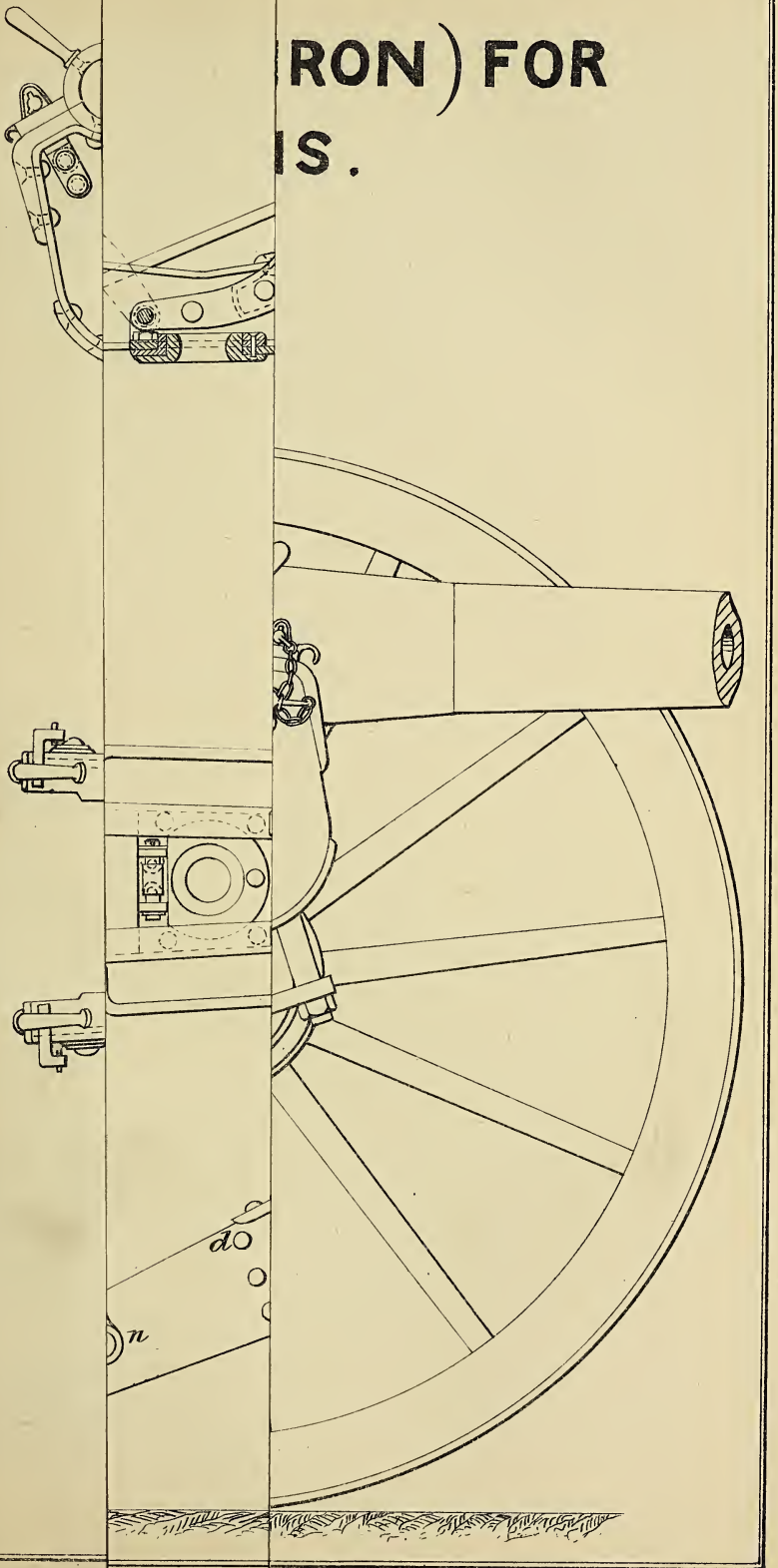


NEW FIELD CARRIAGE (IRON) FOR LONG-RANGE GUNS.

FIG 2. ($\frac{1}{10}$).

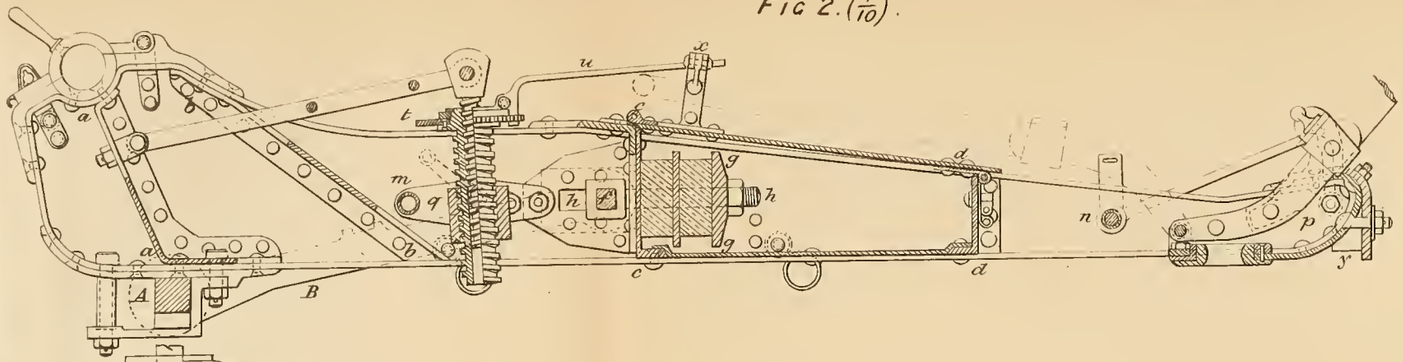


FIG 3. ($\frac{1}{10}$).

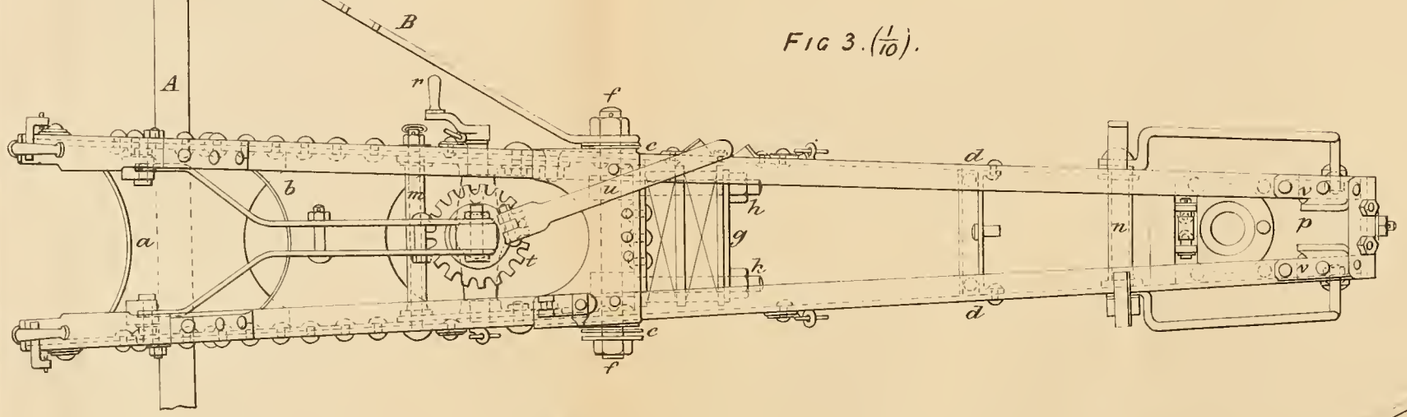


FIG 4. ($\frac{1}{5}$).

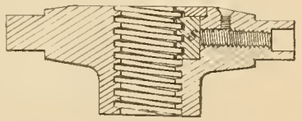
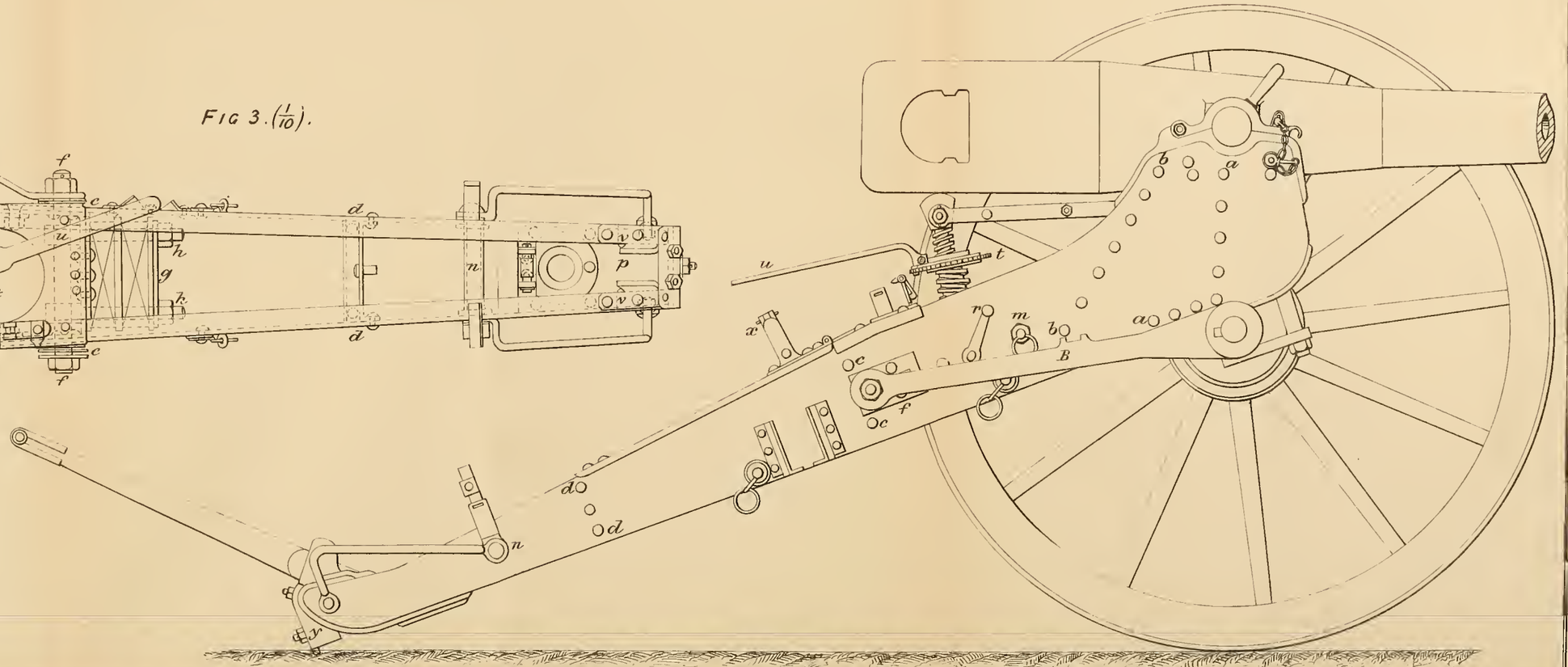


FIG 1. ($\frac{1}{10}$).



THE RÔLE OF HORSE ARTILLERY

IN A CAMPAIGN:

THE R.A. INSTITUTION PRIZE ESSAY OF 1878.

BY

LIEUT. J. K. TROTTER, R.H.A.

"Taliessin is our fullest throat of song,
And one hath sung, and all the dumb will sing."

Introduction.

WHEN the history of military error comes to be written, an important chapter will be occupied by the theories of horse artillery and cavalry, put forward chiefly by Germans, between the Seven Years' War and the middle of the present century. The great egg question in Lilliput was nothing to the dispute which agitated the field artillery world for a century. Six revolutions attested the unwillingness of a large portion of the people of Lilliput to obey the law forbidding the breaking of the larger end of eggs, and at various periods no less than 11,000 persons suffered death rather than break the smaller end. But although the two factions which distracted this unfortunate empire were unable to agree as to the use of an egg, they freely admitted that an egg was an egg, and nothing else. In the artillery controversy, however, not only were the disputants divided as to the *use* of horse artillery; they were not agreed as to the *nature* of horse artillery. Horse artillery, said one faction, is not artillery at all; it is cavalry. A division of cavalry and its horse artillery could only be regarded as a single inseparable whole; * and this horse artillery should never be removed from its cavalry, "even though it may have to remain inactive at first." † The fundamental principle of the field batteries was rest; that of the horse artillery was motion. ‡ The only hope, therefore, for the horse artillery was its immediate and complete

* "Un seul tout inséparable." "Tactique de l'Artillerie à cheval avec la Cavalerie." Par le Gen. Monhaupt. Translated into French by Baron de Pesetsdorf. P. 12.

† Decker's "Cavalry and Horse Artillery." Translated by Begbie. P. 260.

‡ "Das element der Fuss Artillerie ist der Stand, das der Reitenden die Bewegung." Monhaupt, "Die Reitende Artillerie, was Sie ist, &c.," p. 13.

separation* from that "bastard growth,"† the field batteries, which were at bottom infantry, ‡ and which had little more in common with the horse artillery than a metal tube and the doctrine of the trajectory. § Did the unitiated venture to doubt the existence of these profound differences between a battery of six guns, each drawn by six horses, with the gunners mounted on horses, and another battery of six guns, each drawn by six horses, with the gunners on foot, or mounted on the carriages; or attempt to institute a comparison between the horse artillery and the light and active frigate on the one hand, and the field battery and the slow and majestic ship of the line on the other, such rash persons were warned that the internal and essential differences between the two were far greater and more weighty than the external and superficial resemblances by which they had permitted themselves to be carried away. ‖

In order to illustrate the tactics of horse artillery, a number of books were written by the Deckers, Monhaupt, &c., which afford a melancholy example of the absurdities to which soldiers can lend themselves in defence of a preconceived theory. The evolutions they proposed never were practised, so far at least as the history of tactics can be trusted, and probably never could have been practised, because, instead of being founded upon facts deduced from the actual experience of war, they were based upon certain assumptions, which, judged by the light of modern experience, can be safely written down as unreasonable and absurd.

It will be profitable to inquire what have been the uses of horse artillery in the past. This arm was created by Frederick the Great, for the double purpose of supplying the army at large with a mobile field artillery, and the cavalry with a suitable support, capable of following its movements without hampering them.

During the latter part of the Seven Years' War, the horse artillery did little or nothing in the field. It is said to have been destroyed at Kunersdorf and Maxen; but there is absolutely no proof that such was the case. It was during the earlier wars of the French Revolution that this arm first came into notice through its "canister tactics." The movements of infantry were then slow and complicated, and the effective range of the ordinary musket was certainly not over 300 yards, while canister was effective to at least 500 yards. Under these circumstances, a brilliant *rôle* was possible for the horse artillery, and the French, driven to bay, turned its powers of rapid movement to the best account. Whilst the lumbering field batteries were toiling after their divisions far in the distance, the flying artillery was "hurrying from point to point of the battlefield with the speed of lightning; now protecting the hard-pressed infantry, now supporting the wavering cavalry. At one moment the horse artillery galloped up to canister range, and annihilated

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* Decker, *ibid.*, 267.
† "Zwittergeburt." Decker, "Taktik der drei Waffen," p. 120.
‡ Monhaupt, *ibid.*, p. 13.
§ C. Decker, "Geschichte des Geschutzwesens," p. 154.
‖ Monhaupt, *ibid.*, pp. 24, 25.

the enemy's ponderous columns before they could be deployed; at another they dashed round his flank, and by their unexpected fire threw his troops into irretrievable confusion."* Such was the use of the horse artillery in the Waterloo era; but the days of long range and breech-loading small-arms, and the development of line tactics, put an end at once and for ever to this brilliant system of attack. The days of "canister tactics" are over, and, in so far as its fire is concerned, horse artillery has been a heavy loser.

Present uses of H.A.

So much for horse artillery in the past. Passing on to the more important branch of the subject, its present and future, it may be well to commence by inquiring, Has horse artillery lost, on the whole, by recent tactical developments, and by the improvements in firearms? This will be best answered by another question: Has the value of mobility decreased? The reply to this can be in no way doubtful. Far from having decreased, the value of mobility has increased enormously. The causes of this increase in the value of mobility are so numerous, so apparent, and so generally acknowledged, that it will be unnecessary to enter into them here. It may be just stated that the great increase in the extent of positions occupied by armies on the defensive, as well as in the area of ground over which troops will have to move to the attack of points defended by long-ranging arms of precision, has done much to enhance the value of mobility. It is true, beyond doubt, that the old tactics of horse artillery have disappeared for ever, and with them happily has been swept away a collection of absurd theories as to the sacred nature of this arm, and the supposed differences between it and the field batteries; yet there still exists in modern tactics a *rôle* for horse artillery, the duties of which are more important and more onerous, and therefore more honourable, if less brilliant, than any it ever had to perform in the past. A very little consideration will show that this is the case. It is no mere figure of speech to say that horse artillery will be called upon to play a part in war second in importance to that of no other branch of the service at the present day. It is the one arm whose labours never cease from the moment that an army enters upon a campaign till its conclusion. Cavalry, infantry, even the divisional artillery, have their periods of inaction, but for the horse artillery there is no rest. With the cavalry of the advance, or with the advanced or rear-guard; at every stage of the attack or defence of a position; in pursuit or retreat, the presence of horse artillery will always be necessary. There is hardly any conceivable phase of war, in fact, except where the ground precludes its employment, in which its services will not be required.

In order to consider the duties of horse artillery in detail, the subject may be divided into the following heads:—

(1) Duties in connection with the cavalry.
(2) Corps artillery.

Before entering upon this branch of the subject, I may as well say

* "The Mobility of Field Artillery." Capt. Hime.

here that I am far from wishing it to be supposed that everything stated below is held to be exclusively applicable to horse artillery. It will be enough to prove merely that it is essential to horse artillery. The duties of the horse artillery and the field batteries touch each other so closely in most respects, that it is impossible to draw any broad line of distinction between them. The field battery is, in fact, in respect of its mobility, but a modified form of the horse artillery battery; the horse artillery battery, in respect of the efficacy of its fire, a modified form of the field battery. The development of the mobility and independence of field artillery has done much to bring the horse artillery and field batteries closer together. The one has been to a great extent separated from, and rendered independent of, the cavalry; the other has been more and more dissociated from the infantry, and has become so mobile that the term "foot artillery" can be no longer justly applied to it.

Duties in connection with the Cavalry.

H. A. with cavalry.

Under this heading are included all the duties of horse artillery, when acting with cavalry independently, beyond the reach of the support of infantry. These duties may be considered, for the sake of convenience, under the following headings:—

a. Duties with cavalry of the advance.
b. „ „ detached force of cavalry.
c. Pursuits.
d. Retreats.

Cavalry of the advance.

a. With the Cavalry of the Advance.—It may be taken for granted that the advance of armies, where the nature of the theatre of war permits of it, will always be preceded by a large force of cavalry in the form of what is now generally termed "the strategic veil." The duties of this force are on all hands admitted to be exceedingly important, and upon their efficient performance depend not only the security and comfort, but also, to a great extent, even the *morale* of the main body of an army. These duties are, briefly, to cover the advance of the main body with a veil of cavalry scouts, and to conceal from the enemy everything that takes place behind this veil; to fasten on the enemy, and to gain all possible information concerning his strength, movements, &c.; to secure the repose of its own main body, and, where it is possible, to interrupt that of the enemy.

This cavalry force, in an army organised like our own,* would be furnished by the cavalry brigades of each army corps, which, when two or more corps were acting together, would be formed into a Cavalry Division. The horse artillery accompanying this force would consist of the battery attached to each cavalry brigade, and to these

* Here and elsewhere the organisation is supposed to be that of the mobilisation scheme.

might be added, if there should be any special need for their services, one or more horse batteries of the corps artillery. As a rule, however, it would be undesirable to attach a large number of batteries to this force, for its business is "not to fight, but to watch and report;" * and by unnecessarily augmenting the artillery, the services of a considerable force of cavalry would be taken up in escorting or supporting it, and the commander might be tempted to assume a *rôle* by no means suited to the part of the cavalry veil. It may, however, be fairly questioned whether the cavalry of the advance will always be able to carry out the duties assigned to it without some use of force. Since the development of the strategic veil, no campaigns have been fought, in which the cavalry forces on both sides have been at all equally matched.† Where this is the case, unless some force is used, the cavalry of two hostile armies will probably simply neutralise each other. We find Napoleon III. blaming his cavalry leaders in the Franco-German War for not having penetrated the enemy's cavalry veil.‡ Again, the author of the Royal Artillery Institution Prize Essay for 1876 recommends the increase of the horse artillery with the cavalry of the advance, on the ground that one surplus battery may succeed in "rending the enemy's strategic veil beyond repair for the campaign." §

The duties of the horse artillery attached to the cavalry of the advance will be confined to supporting the cavalry and co-operating with it in any attempt to penetrate the enemy's cavalry veil, or to force back his cavalry upon the main body; frustrating any similar attempt on his part; extricating the cavalry from an engagement.

To lay down any rules for the action of the horse artillery, when performing these duties, is manifestly impossible. It may be stated broadly that, if on the offensive, it should seek the enemy's flanks, especially when attacking any points that have been artifically strengthened; if on the defensive, it should endeavour to take up commanding positions on or near to the main roads. It is scarcely necessary to add that it must always be where it can rely upon the immediate tactical support of a considerable force of cavalry. On the march it will generally be advisable to keep to the main roads, not only on account of the extra labour which bad or indifferent roads will entail on the draught horses, but also because it is on the main roads and at central points that the principal opportunities for its action will occur. It is evident that for the efficient performance of its duties the greatest mobility is necessary, and it must under all circumstances be able to keep up with the cavalry, otherwise it will only hamper the movements of the latter. The force will have to act quite independently of, and at considerable distances from, the main body. It must be prepared to make long marches, and to con-

* "Précis of Modern Tactics." Home.

† That the part of strategic veil was not developed in the war of 1866, the following will show: "Thus the outposts of both armies faced each other on this day, within a distance of 4½ miles, without either army suspecting the near and concentrated approach of the other." Official account, translated by Hozier and Wright.

‡ "Campagne de 1870. Par un officier attaché à l'État Major Général."

§ Royal Artillery Institution Proceedings, vol. ix., p. 442.

centrate upon any point on the shortest notice. Owing to the great area over which the cavalry will have to be extended, the horse artillery, in order to give due support to every portion of the front, will have to act in small units. It will sometimes even be necessary to break up a battery into divisions or half-batteries. Tactical knowledge is therefore indispensable to the battery officers. The place of the horse artillery on the march will naturally be with the cavalry supports or main body.

Detached force of Cavalry and H. A.

b. Detached Force of Cavalry and Horse Artillery.—It is necessary that this employment of cavalry and horse artillery be distinguished from that of the cavalry of the advance, from which it differs essentially. It has been shown that it is the duty of the latter force to avoid fighting if possible. The former, on the other hand, is detached from the main body with the purpose of attaining some specific object, which, in the great majority of instances, can be done only by fighting. Again, when acting with the cavalry of the advance, the horse artillery plays but a subordinate part; but, in this case, it will frequently become the principal arm, and will be employed, as pointed out in the Royal Artillery Institution Prize Essay for 1876, to attack the enemy's dispositions under the protection of the cavalry.*

Some of the objects which such a force may be called upon to accomplish are—to seize some important strategical point before the enemy can reach it, to put it into a state of defence, and hold it till the arrival of the main body; to fasten on a retreating enemy, and to hold him till the infantry can come up and attack him, as in the oft-quoted case of Mars-la-Tour; to protect the exposed flank of an army making a flank march, or *vice versâ*, to attack the exposed flank of an enemy under similar circumstances; to check a pursuing or to pursue a beaten enemy. (This last case will be considered under the head of "Pursuits and Retreats.")

As this force is essentially a fighting force, it will necessarily be much stronger in artillery than the cavalry of the advance. This artillery will, as a rule, consist of the horse batteries attached to the cavalry, and will be supplemented by the whole or a part of the horse batteries of the corps artillery. The nature of its duties will almost always render mobility of primary importance, and therefore horse artillery will be selected; but, should the particular object which it is called upon to undertake be one requiring no special display of mobility, then the field batteries of the corps artillery may be sent, and should even be preferred to horse artillery.

The great increase in the temporary retaining power of relatively small bodies, due to the introduction of breech-loading small-arms, † has done much to increase the importance of an independent force of cavalry and artillery. By seizing upon some important point, putting it into a state of defence, and making use of dismounted troopers as infantry, a greatly superior force could be kept at bay for long enough. By thus developing the defensive powers of cavalry, such a force might

* Royal Artillery Institution Proceedings, vol. ix., p. 442. † Wellington Prize Essay.

act with far greater boldness than would be justifiable for an infantry force under similar circumstances, for its power of rapid movement would enable it to be comparatively indifferent about its flanks and rear, especially if the attacking force should be composed of less mobile troops. It is on occasions such as these that the advantages possessed by troops fighting behind hastily constructed entrenchments, which have been brought so much into prominence during the recent war, will probably exercise a great influence both on strategy and tactics. When the object of this independent force is to hold a position, a part of the artillery would be employed with the dismounted cavalry in the defence, taking care to entrench itself when time allows, whilst the remainder with a cavalry force would be kept in hand to act offensively and to threaten the enemy's flanks should he attack.

A force of cavalry and artillery employed to hold an enemy fast in a position will naturally be as strong as possible in guns, and field batteries may be freely used in combination with the horse artillery and cavalry. As its object must be to keep the enemy at a distance, and to avoid bringing on a serious engagement, it must be careful to keep out of the range of the effective fire of infantry; and must be prepared to withdraw, if seriously attacked. It must not, however, fall into the error of allowing the enemy, by assuming the offensive, to accomplish his object of withdrawing from the position, leaving only a rear guard, and if necessary it must be prepared to sacrifice much, in order to stay his retreat. If protected by cavalry on its flanks, it should be able to hold its ground against any infantry attack in front. At Mars-la-Tour, the German artillery, without the support of infantry, succeeded in repulsing every attempt of the French infantry to advance to the attack of the guns. * As soon as ever the French infantry showed themselves, they were exposed to such an accurate and destructive fire from the German guns, that they were always obliged to retire.

The occasion of an enemy's making a flank march is one which offers great opportunities to the cavalry and artillery, and which should ever be turned to the best account. The operation is so difficult and delicate, and the results of failure so disastrous, that it will generally be worth while to risk much in order to make the most of it. Whilst a small force of cavalry endeavours to break up the roads in front of the enemy and to impede his progress, the remainder, with all the available horse artillery, and even with field batteries, should attack his columns with the greatest boldness and vigour. Troops, especially when on the march, are so susceptible to flank attacks, that it will be comparatively easy to produce confusion and demoralisation amongst them. Even should this force not be able to drive the enemy's columns off the roads or force him to form front to a flank, it may at least so delay his march, harass his movements, and demoralise his troops, as to enable its own main body to come up and attack him at a disadvantage, or to devote the time gained to manœuvring.

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* Hoffbauer.

The action of a force of cavalry and horse artillery employed to cover the flank of an army making a flank march will be similar to that of the cavalry veil, with this exception, that it will have to be prepared to fight, and must therefore be very strong in artillery. The whole flank of the column must be covered by cavalry scouts, with supports and reserves at central points. In order to provide for the security of the exposed flank, and to give timely notice of the enemy's approach, the force should be at a considerable distance from the main body, and should not depend upon it for support. It must be prepared to concentrate upon any point, and to act against the enemy's cavalry and horse artillery.

The above are but a few of the instances of the independent action of cavalry and artillery. It is easy to conceive of many other cases in which they might render signal services during a campaign. It may be said, in fact, that there is hardly any limit to the employment of such a force for the carrying out of objects at such distances from the main body of an army as to render the action of infantry impossible.

Retreats.

Retreats.—The objects which the cavalry and artillery will be called upon to secure during a retreat, and the manner of their employment, will be identical in almost every particular with those of the force covering the exposed flank of an army making a flank march. The duties of this force must not be confounded with those of the rear guard, with which they have little in common. During a retreat, the safety of the army depends, in a great measure, upon the handling of the covering force of cavalry and artillery. There is no duty in war which calls for a greater display of the highest military qualities, for to perform it efficiently this force must be superior to the demoralising and disheartening influences which are sure to affect the main body in a greater or less degree. Its position must not be in rear of the retreating army, but on its flank, for it is there that the enemy will endeavour to inflict his blows. To adopt the old plan of blocking the roads in rear of a retreating army with cavalry is not only to make a manifestly improper use of one of the chief weapons of cavalry, the speed and power of its horses,* but also to confer a great advantage upon the enemy, who would be at liberty to outflank the rear guard, and attack the flanks of the retreating infantry, with little fear of molestation. The result, moreover, of a sudden panic amongst a large cavalry force closing the retreat of an army—and no troops are so liable to sudden panics as cavalry—would probably be fatal to the whole force.†

Pursuits.

Pursuits.—The retaining power and the increased range of breech-loading small-arms have undoubtedly taken something from the power formerly possessed by cavalry and horse artillery of converting a defeat into a rout. It will rarely be safe to assume that beaten infantry are

* "Précis of Modern Tactics." Home.
† "The French Cavalry." Col. Bonie.

so demoralised as to be unable to inflict a loss upon cavalry infinitely greater than the cavalry can hope to cause them. At the right moment, moreover, the cavalry will hardly ever be in a position to fall upon the disordered enemy. During the course of an attack, it must be kept out of the range of the effective fire of infantry and artillery, so that a considerable time must elapse before it can be in a position to take advantage of any success. The whole of the artillery, too, will generally be employed in the attack or defence, and at the moment of success is sure to be more or less exhausted. To disengage the horse artillery from the artillery line, to combine it with the cavalry and to launch them against the enemy must ever be a work of time. When the enemy is not completely demoralised, an attack without method will be sure to fail. In the rare cases, however, when the enemy is completely demoralised and incapable of further resistance, he should be followed up immediately by all the available cavalry and artillery in any formation which may be most convenient at the time. The old maxim that the "last breath of man and horse must be devoted to the pursuit" * still holds good; it is the opportunities for its application which are wanting at the present day. Horse artillery and cavalry will be in the most favourable position for making the most of a success when they are acting together on the flank of a flank attack. When such an attack is successful, they should endeavour to get completely round the enemy's flank, to a position where they would be able to take the second line in flank, or even in rear, to throw his reserves in confusion, and to threaten his line of retreat. It is, however, when an enemy is making a continued retreat of many days that the cavalry and artillery will be able to inflict the greatest loss upon his troops. Whilst the heavier batteries might occupy the rear guard, and give employment to a part of the enemy's cavalry, all the available cavalry and horse artillery should be despatched to outflank the rear guard, pass every obstacle, and cut in upon the flanks of the enemy's columns. This force will probably effect most when it is broken up into small parties, linked together by cavalry scouts, each detachment of cavalry being accompanied by a battery of horse artillery. Such a force, vigorously handled, might produce such a state of demoralisation in a retreating army as to render it incapable of any offensive effort throughout a campaign. "This use of cavalry and horse artillery is one capable of great development, but, like all such operations in war, is dependent on the skill of the leader." †

In considering the employment of an independent force of cavalry and horse artillery, one fact can hardly escape notice. This is that the retaining power, and therefore the independence, of such a force would be very greatly increased by the addition of one or two Gatling guns to each battery.

Corps Artillery.—The corps artillery is the special artillery force which is kept under the immediate control of the corps commander, and

Corps artillery.

* "Studies on Troop Leading." Verdy du Vernois.
† "Précis of Modern Tactics." Home.

is used for the purpose of striking a decisive blow. It is the only artillery force which is perfectly free to act wherever its services may be required. The divisional artillery is charged with the duty of supporting its division; the horse artillery batteries of the cavalry brigades must follow the movements of the cavalry. The corps artillery is hampered by no such conditions. Wherever opportunities occur for bringing about great results by means of artillery fire, there is the place for the corps artillery. It may even be detached from its own, to the aid of another corps. In the war of 1870-71, the German leaders, following the old French maxim of marching towards the sound of guns, used to despatch their corps artillery to take part in battles where the co-operation of the main body of the corps was impossible. It is plain that, the sphere of action of the corps artillery being so wide, it must possess considerably greater mobility than is sufficient for the divisional artillery. For this reason the greater part of the corps artillery consists of horse artillery batteries, the proportion in this country being three horse artillery batteries to two 16-pounder batteries.

The employment of the corps artillery may be considered under the following heads:—

(*a*) Advanced and rear guards.
(*b*) In the attack of a position.
(*c*) In the defence of a position.

Advanced and rear guards.

(*a*) The employment of the artillery of the *advanced and rear guards* has been so exhaustively treated of in the Institution Prize Essay for 1874, that it would be mere repetition to enter into it here. It will be well just to notice that horse artillery is peculiarly suited for these duties, owing to its mobility and to the comparatively large number of rounds of ammunition which it can dispose of.*

In the attack of a position.

(*b*) *In the attack of a position.*—Closely connected with the employment of the corps artillery on the offensive are two important questions, which may be conveniently considered here. The first is, Is it desirable under any circumstances that artillery should be kept in reserve? To a man, the German school are against the bare mention of such a thing. In support of their views the experience of the Franco-German War is quoted to show that the withdrawing of guns from the artillery line, in order to employ them in another part of the field, is an operation attended by no great difficulties, † and that it is absolutely essential that every gun should be in action throughout every period of the attack. ‡ On the other side it may be urged that it is only by taking immediate advantage of the opportunities which occur at critical moments that great results can be obtained; that the withdrawing of batteries already in action to another part of the field is a matter of time; that it is an operation which cannot fail to attract the enemy's

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* "Studies in Troop Leading." Verdy du Vernois.
† "The German Artillery." Hoffbauer. ‡ Becker.

notice, and that he will therefore be in a position to adopt any precautionary measures that may be needful. The truth is that the term "reserve artillery" is evidently misleading, and has been the cause of artillery being kept out of action till too late to have any effect on the fortunes of the day. This was undoubtedly the case with the French artillery at the battle of Gravelotte. It seems to be possible, however, to fall into an error exactly the reverse of this, viz., to hurry every available gun into action against the enemy the moment his position is discovered, without waiting to consider how he may be attacked to the greatest advantage. The artillery of the German 9th Corps fell into this error at the same battle (Gravelotte—St. Privat), when it rashly advanced to the attack of the French position, Amanvillers—Montigny-la-Grange, unsupported by infantry and utterly ignorant of the dispositions of the enemy. The result of this attack was that the batteries engaged suffered enormous losses; the general plan had to be modified, and it was deemed necessary to occupy the attention of the French by an attack on their left and left centre, which proved not only unsuccessful, but extremely costly. * Between these two extremes it is surely possible to find the proverbially safe middle course. It is hardly too much to expect at the present day that an artillery attack should be made with some plan. If it is to be laid down as a rule, as seems to be generally assumed, that an artillery attack is to consist of a mere concentration of all available guns on the batteries of the advanced guard, then artillery tactics have become at once simple and unscientific. It cannot but be possible to find some modification of such a plan. Most writers divide the artillery attack into two or three periods, the first of which is devoted to searching out the enemy's position, feeling for the weak points, and endeavouring to draw the fire of his guns, while the commander is deciding upon his plan, and the infantry is deploying for the attack. There can be no absolute necessity for bringing every gun into action at the first stage of the attack. This period might be profitably utilised in considering and deciding upon the positions which the artillery must occupy at the decisive stage, and the method of bringing the different batteries up to these positions. Whilst the enemy is being engaged by the artillery of the advanced guard, and of the nearest infantry divisions, the batteries of the corps artillery, which remain in the hand of the commander of the corps, and all the rest of the artillery, should be manœuvred into such positions, out of sight of the enemy, if possible, that, at a given signal, the whole may move forward together to the decisive stage in the shortest possible time, and bring a converging or flanking fire to bear upon those points which offer the greatest prospect of success to the infantry attack. Or again, the whole of the horse artillery with the cavalry might be sent forward in the preliminary stage to search out the enemy's position, and to occupy him, whilst the heavy batteries were taking up positions, previous to advancing to the decisive stage. To concentrate the whole of the artillery upon the guns of the advanced guard in the preliminary stage

* "The German Artillery." Hoffbauer.

of the attack is to give up many of the peculiar advantages of the initiative. The commander is more or less tied down to a certain line of action; the position and strength of the assailants' artillery, as well as the ground over which he must advance to the decisive stage of the attack, is made apparent to the enemy, and the power of so placing his guns with regard to the position of the enemy, as to bring a flanking or converging fire to bear upon the chief points of attack, is either left to chance or absolutely thrown away. It is evident that the necessity for a scientific handling of the artillery increases in the inverse ratio to the size of the army, and this is a fact which we in this country would do well to remember. Where very large armies are engaged, the difficulty of manœuvring the artillery will, no doubt, be enormously increased on account of the impossibility of finding space for the bringing into action of large masses of guns.

The second point of importance in connection with the employment of the corps artillery is—How far is it possible to separate the action of the horse artillery from that of the field batteries? That it is desirable to separate them can hardly admit of a doubt, both because when they are kept together, the special advantages of one or the other must be in some degree sacrificed, and also because, when batteries of different calibres are intermixed, the supply of reserve ammunition, a matter of the greatest importance at the present day, becomes exceedingly complicated. Yet in the great battles of the Franco-German War, the artillery masses of the Germans were formed of batteries of different calibres, mixed indiscriminately, without regard to their special features. In some measure this may be accounted for by the peculiar and exceptional nature of the artillery fights in the chief battles; but it may be fairly questioned whether it will not be possible in the future to improve upon the German artillery tactics of 1870. It seems probable, however, that when large artillery masses are employed, the intermixture of batteries of different calibres will be always to a certain extent unavoidable, and this will be the case more especially when the ground will only allow of the action of a limited number of guns. In order to minimise the inconvenience resulting from the mixing of batteries of different calibres, it will be necessary to insist on the artillery divisions being kept together, except when this is absolutely impossible. The neglect of this rule must inevitably result in a great loss of manœuvring power, and probably also of unity of action; the links connecting each battery to its corps or division commander will be snapped, and the services of the staff of the artillery division will be lost to some, if not to all, of the batteries of the division at the moment when they are most needed. A further advance or a retirement under these circumstances would hardly be carried out without great confusion.

But there are occasions when the action of horse artillery will be sufficiently distinct. Owing to the great sacrifice of life which must attend any attempt to pierce the centre of a position defended by breech-loading rifles, it seems probable that an army on the offensive will almost always attack one or both flanks of an enemy. In the

carrying out of such a flank attack, the horse artillery batteries will naturally be used, and they should be despatched with the cavalry during the time that the advanced guard artillery is engaged in carrying on a delaying action with the enemy. The cavalry will protect their outer flank, and they must endeavour to get round the flank of the enemy, and even, if possible, to take him in rear. From this position they will be able to take advantage of a successful attack, or to act against the flank of the enemy, should he attempt to advance. In such an attack the first consideration must ever be the developing of it at the right moment. The necessity for timeliness of action has been dwelt upon by every artillery writer since the publication of the famous "Tactical Retrospect." In the case of a flank attack it will be necessary for the artillery not to come into action until the troops destined to assault the position are sufficiently near to take advantage of the effect of their fire before the enemy can reinforce his threatened flank. The remainder of the artillery will co-operate by keeping the enemy occupied along the whole front, and by bringing a cross fire upon the points which are to be attacked. If the enemy's flank is thrown back to meet the attack, the heavy batteries should endeavour to enfilade it.

In the critical stages of the attack of a position, opportunities will occur for a bold use of the most mobile batteries. Military theorists have not yet settled how far it is possible for artillery to venture within the range of the effective fire of infantry; few, however, have been found to deny that, under certain circumstances, artillery may and must be pushed up to close quarters at all hazards. It is not difficult to imagine a case. Suppose an infantry attack to be taking place. Up to a certain point it progresses rapidly, and with every prospect of success. At length comes hesitation, a check, a tendency to lie down and fire. All available supports and reserves have been absorbed into the firing line. The attack wavers between success and failure. An impetus is needed to carry it forward again. This is the opportunity for the artillery, and especially for the rapidly moving horse artillery. A swift advance on the flank of the wavering infantry will give the desired impetus. The infantry will be encouraged by the close support of the guns, and the latter, even if they effect little by their fire, will at any rate relieve the pressure on the infantry, by drawing upon themselves the enemy's fire. It is hardly possible to study the history of battles without being struck by the almost infinitesimal difference which frequently separates success from failure. This leads to the conclusion that the close support of artillery at critical moments will often be the means of enabling infantry to achieve a success which would otherwise have been impossible, and will justify almost any sacrifice. But for such a use of artillery several conditions are indispensable. (1) The commander must be on the watch for the right moment, and must be careful neither to anticipate it, nor to advance when the fate of the attack has been already decided. (2) The ground over which the advance has to be made must have been previously reconnoitred by officers, who should, when it is possible, themselves lead the batteries into their positions. (3) The advance must be made very rapidly,

simultaneously, and on as broad a front as possible. Whenever an artillery commander has established a number of guns in a position, within the effective range of the infantry fire of the enemy, without suffering great loss, he has gained an advantage, both moral and material, which cannot fail to produce some effect upon the operation in which he is engaged. This is a fact the importance of which it is difficult to exaggerate. Artillery frequently suffers the greatest loss when limbered up and out of action. Too great stress, therefore, cannot be given to the necessity of devoting time and study to the art of leading a large force of guns into action when under the effective fire of an enemy in position.

In defence of a position

(c) *In defence of a position.* The horse artillery will have many opportunities, during the defence of a position, of acting in a special manner. When the enemy is approaching the outposts of the position the horse artillery batteries, with the cavalry, should be sent to the front to compel him to deploy as far as possible from the defender, and to discover his strength and dispositions. Eventually this force will be compelled to retire and to seek shelter in the main position. It would be desirable as a rule not to post the horse artillery batteries in the line of defence, but to keep them in central positions, and await the development of the enemy's attack, so that they can be despatched at a moment's notice to any part of the line which may require support. When an enemy attacks a position along the whole front, as well as in flank, he generally finds one or more weak points into which, if he succeeds in penetrating, the position must eventually be abandoned. To the support of these points the horse artillery batteries must be directed, and they will be most likely to hold the enemy in check by acting offensively and advancing against the flanks of his attack. The necessity for having some batteries in hand for such emergencies can hardly admit of a doubt. It will avail little to the defensive to have all its artillery in action in well-chosen positions, and to keep the enemy in check along the whole line, if there be but one point into which he succeeds in forcing his way;—in fact, one great advantage of the initiative consists in this, that an assailant repulsed at twenty points, and successful at one, is probably successful on the whole. The moral pointed to by this fact, as far at least as the artillery is concerned, is, not that it is necessary to have a large reserve of guns massed in a central position, but that a few mobile batteries should be kept in hand at the critical stages of the attack, so disposed that any part of the line may be reinforced on the shortest notice. When the assailant is about to execute a flank attack, the cavalry scouts should be able to give notice of the march of his columns towards the threatened flank, and the horse artillery and cavalry should be launched against them, and should endeavour to hinder their movements. If the French cavalry and horse artillery, at the battle of Gravelotte—St. Privat, had attacked the Saxon army corps when it was making its flank march to the attack of Roncourt and St. Privat, and had impeded its progress for but one hour, the result of the battle must have been different. This shows

the necessity of defeating or disarranging the plans of the assailant by a vigorous offensive use of cavalry and horse artillery. This force might eventually be posted on the threatened flank and prolong the line, so as to throw the enemy farther off* and to compel him to make a wider detour, in order to envelope the flank. The artillery which takes part in the defence of a position should never quit the position for the purpose of retiring as long as there remains the smallest chance of the enemy being repulsed. When the horses and limbers are under cover, which would almost always be the case when artillery is defending a position, there can be no reason why the guns should not remain in support of the infantry till the latter are compelled to retire. To leave the infantry at the critical stage of the attack, even though a better position can be found in rear, is to ignore Napoleon's famous maxim as to the comparative value of moral force; and to encourage in artillery officers the commonly received idea that the appearance of the enemy's infantry at any range under 1000 yards is to be the signal for the immediate removal of their guns to a place of security is surely not prudent. In the event however of its being necessary to withdraw from a position, the horse artillery batteries will have to cover the retreat of the infantry and to disengage it. Their superior mobility will enable them to remain in action till the last moment, and they must seek to occupy the enemy whilst the infantry is taking up a fresh position. Before retiring, the ground should be carefully examined in rear. If this is not done, confusion, crowding, and probably great loss, will be the result. It is especially necessary to guard against this in a retirement, not only for the sake of the artillery, but also on account of the infantry in rear, whose *morale* it must ever be the object of the artillery to preserve.

Conclusion.

The grand conclusion to be drawn from the foregoing remarks, and the facts they embody is, that it must always be the endeavour of horse artillery to gain in time what is lost in power. Horse artillery, using the word in its original and ordinary sense, is the lightest branch of the field artillery service, with its gunners mounted, and it was called into, and has been kept in existence for the purpose of carrying out duties for which ordinary field batteries are too heavy. Be it desired to send forward a force of cavalry at all speed to anticipate the arrival of a train full of troops, or to occupy an important position at a considerable distance to the front of the main body: be it desired to despatch a division of infantry through some mountainous and difficult country, such as the north of Spain; then if the artillery is to accompany these troops, the artillery should be horse artillery. And why should horse artillery be selected? Obviously because field batteries would be too cumbrous. But it may be said, such duties could frequently be performed by field batteries, *i.e.*, the mobility of field batteries is sufficient in certain cases to enable them to act with cavalry or infantry for the performance of special duties. When this is the case, then field batteries should by all means be sent, for common

* "Précis of Modern Tactics." Home.

sense dictates that *the proper artillery for any service is the heaviest calibre that can be used to carry it out.* The destructive effect of guns increases in *at least* the direct ratio of their calibres, and it would therefore be madness to persist in employing only 9-pounders where 16-pounders, or even 40-pounders, could be equally well employed. It is owing to forgetfulness of this simple principle, *i.e.*, that the proper calibre for any given duty is the heaviest which can be effectively employed, that so many errors have been, not only laid down in theory, but carried out in practice. Misled by the outcries of a few fanatics, such as Monhaupt, Decker, &c., artillery and other officers have frequently drifted into the belief that some special and peculiar sphere of duties belongs to the horse artillery; that it is incorrect and improper to employ other artillery for such duties; and that in given junctures it might be strictly correct to use only horse artillery, although it might be possible to drag 40-pounders into the critical position at the critical moment. To discuss such a theory would be mere waste of time. It is enough to say here, that an officer who employed a light where he might employ a heavy calibre, in obedience to preconceived theories, would hardly prove an honour to his regiment or country. But there are occasions, and these by no means rare ones, in which the heavier calibres cannot be brought to the proper point at the proper moment; hence the necessity which always has existed, which still exists, and which always will exist, as long as the horse is the means of artillery draught, for a certain proportion of the lightest calibres on the lightest system, to act on such occasions. I cannot agree with the theory occasionally expressed that even the lightest calibres, equipped on the field battery system, with gun axletree seats, should ever take the place of horse artillery. In the first place the gun axletree seat system is not the lightest system possible. To work a gun properly, at least six men are required, and to bring these six men up on the field battery system involves carrying three men on the gun limber and two on the axletree seats; in all, three men more than are carried by the horse artillery. This is equivalent to adding about 36 stone, or 4·5 cwt., permanently to the weight behind the team. This might not tell in a battle or in a day; but it surely would tell in a week's marching. But, in the second place, it is unscientific and unpractical to reduce the field batteries to the horse artillery calibre. A gun which is light enough for the horse artillery, *i.e.*, for duties requiring the greatest celerity, is manifestly too light for the field batteries, *i.e.*, for duties *not* requiring the greatest celerity. On the other hand, a gun heavy enough for the field batteries is as evidently too heavy for the horse artillery. The efficiency of field artillery is dependent upon two main principles, which work in opposite directions, *i.e.*, mobility and shell-power. The former may be said to be represented in a special sense by horse artillery; the latter by field batteries. Neither principle, of course, can be sacrificed to the other, but of the horse artillery it may be said that—given an amount of shell-power sufficient for the efficiency of the system—it must be combined with the greatest possible mobility; of the field batteries—given an

amount of mobility sufficient for its efficiency—it must be combined with the greatest possible development of shell-power. When, therefore, it is found that the duties of the horse artillery can be performed by field batteries, it is reasonable to assume either that the mobility of the horse artillery or the shell-power of the field batteries is capable of further development. From this we are brought to the conclusion that to equip field batteries with a horse artillery gun is to throw away wantonly the greatest advantage of artillery in the field—weight of metal.

In a word, then: while the cavalry divisions should always be accompanied by a certain proportion of horse artillery, horse artillery should only be attached to infantry divisions when operating on ground where field batteries cannot follow. At least half the artillery of the advanced or rear guard, and the greater part of the corps artillery, should consist of horse artillery.

In the varying phases of the battle, horse artillery must reinforce the field batteries, and the field batteries the horse artillery, as circumstances demand; but some of the horse batteries of the corps artillery should be kept in hand for the critical stages of the attack or defence, "like greyhounds in the leash." *

Finally, let us banish from our minds all bygone theories of cavalry artillery and infantry artillery—square triangles and round triangles—and never for a moment forget that if six guns are required for the attack or defence of a certain point, the question to be considered is not what troops are fighting at that point, cavalry or infantry, but what is the largest calibre that can be effectively employed in the attack or defence of the given point?

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* Sir Augustus Frazer.

THE RÔLE OF HORSE ARTILLERY

IN A CAMPAIGN:

SILVER MEDAL PRIZE ESSAY OF 1878.

BY

LIEUTENANT T. S. HOWIE, R.A.

"The strength of field artillery is not to be estimated by the number of guns, but by their efficiency of movement, and by the skill of the men who work them."

Question of effect *versus* mobility.

The question of effect *versus* mobility is an old one which has constantly occupied the attention of the field artillerist with varying results.

Whilst at one time it has been maintained that "the primary condition to be obtained in artillery must ever remain effect," and at another the cry has been for a "maximum mobility combined with only necessary effect,"† at the present day it is decided that both qualifications are necessary, a decision which is carried out in every modern system in the only practicable manner, viz., by the adoption of two calibres.

Still the true value of mobility is hardly yet appreciated, a fact which is shown by the absence of manœuvre from artillery tactics.

This state of affairs is no doubt due, in great measure, to the success achieved by an unwieldy system in the late Franco-German war.

But that war was remarkable throughout for the absence of manœuvre, there was none of "that higher manœuvring which aims at an advantage by deceiving and perplexing the enemy." All was "sheer straightforward fighting."‡

But we have stood quite long enough gaping at that success. There is ample room to carry the science of fighting far beyond the limits then reached, and higher tactics will play an important part in the future.

Changes in artillery tactics.

Constant changes in materiel necessitate constant changes in the theories advanced for its employment in the field.

We must, then, be prepared, when considering such a rapidly developing arm as artillery undoubtedly is, to see old theories overthrown, and new ones replacing them. We have seen the same in the

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† "Development of the Matériel, &c., of Field Artillery from 1815 to 1870." Captain Cooke.

‡ Hamley, 1872.

past. Take for example the once much-vexed question of massing *versus* separating batteries, and that of the correct object for artillery fire. The first rules advanced were, separate the batteries while concentrating their fire, and fire only on artillery when there is nothing else to fire on.

"It should be borne in mind," said Jomini, "that the chief office of all artillery is to overwhelm the enemy's troops, and not to reply to their batteries."*

To-day, the broad rules laid down are: mass the batteries, and let the first object of their fire be those of the enemy.

"It is found best to concentrate the batteries in masses." "The first efforts of artillery on each side are generally directed to silencing the opposing batteries."†

Both these changes are, no doubt, due to the fact of an increase in the number of batteries brought into action; but to whatever cause they may be traced, there they stand, examples of radical changes which have taken place in a very few years in the theories propounded by leading authorities.

It need, then, occasion no surprise if the system at present so much advocated, viz., "the precipitate presentment of the whole of our artillery in one grand battery," be replaced by one which numbers amongst its principles "manœuvre,—opportune, adapted to the movements of the enemy, not in place only but equally in time." ‡

With regard to the second question mentioned above, the object for artillery fire, considerable difference of opinion exists amongst the most recent writers on tactics, especially concerning its use in the different phases of the defence, and the difficulty is not unfrequently got over by propounding the rather vague rule that the fire should be directed against that arm which, for the time being, is making itself most felt. Now, though undoubtedly at each phase of an action the effect of one arm predominates, the others are not idle, but are preparing to take their parts in due time. To follow the above rule is, then, to play into the enemy's hands. For example, if standing on the defensive at the commencement of the engagement, the enemy's artillery will be most felt. But under cover of its fire the infantry are preparing for attack. If then the opposing artillery engage the whole attention of the guns, the infantry is allowed to approach unmolested.

Particular care must be taken to guard against this natural instinct to oppose the whole strength to those troops which are making themselves most felt; if not, "the fire of the assailant's artillery, and the fire of his skirmishing line, will have the effect of drawing on them both the enemy's artillery and infantry fire, and hence it becomes possible to bring up the main body in a much closer formation than is often supposed." § Necessity for manœuvre.

While the heavier batteries engage the artillery, the lighter should be engaged in manœuvring against the dispositions of all three arms.

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* Jomini, translated by Mendall and Craighill, 1873. † Hamley, 1873.
‡ Colonel Smyth, Prize Essay, 1876. § Home, 1873.

What is required is that the duties to be performed by heavy and light batteries, respectively, be well defined. Each should have its distinct *rôle*. Let such be plainly laid down, and there need be no occasion for the objection raised against the adoption of two calibres, viz., the difficulty of deciding upon which to employ on a particular occasion.

At present, beyond a few rules laid down for the employment of horse artillery with considerable masses of cavalry, hardly any attempt has been made to define their respective duties.

But, granted the necessity of manœuvre, it will surely be best executed by the most mobile batteries, which it will generally be allowed are those of the horse artillery.

Two things are required, and only two—effect and mobility.

If the equipment of the horse artillery further the attainment of the latter, let the light field batteries be assimilated to it; having made the real sacrifice of effect, the only object should be to obtain mobility, and it must be a mistake to hesitate on account of the comparatively trifling cost of horsing the detachments to render that mobility as perfect as possible.

The points advocated are, then, the division of artillery into two branches only, viz., heavy field batteries and light horse artillery; the latter to be employed, in addition to the duties generally assigned to it, for manœuvre, supported, when necessary, by cavalry.

But before considering in detail the *rôle* of the horse artillery, it will be necessary to glance at the changes and modifications which have taken place, or are likely to take place, in the employment of the arm with which it is specially intended to co-operate, viz., cavalry.

The action of cavalry.

The principal fields of action for the latter in future wars will be two:

(1) In front screening and reconnoitring.
(2) On the actual field of battle.

Though there are no well-defined rules for its action under the first head, the general principle of the method of its employment is as follows:

A comparatively large independent force is detached in the direction where protection is desired. From it smaller forces are sent out to front and flank, which in their turn send out others still smaller, until, on the edge of the veil which is thus formed, the parties are reduced in size to eight or ten, or even one or two men.*

Thus advanced up to perhaps fifty miles from the main army, and spread over a large extent of country (a German regiment, † in the late war, frequently occupied a front of from five to six miles), its duties are—to cover the movements of its own army; to gain intelligence of those of the enemy; and to take possession of advanced posts.

In general it is not intended that it should fight.

But the stronger of two such forces which meet will endeavour to

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* "Instructions for Cavalry Outposts, &c."

† 589 N. C. O. and men.

break through the opposing veil, and numerous cavalry engagements will doubtless take place.

The weaker side will fall back on its supports, steadily and slowly if possible; but in case of its being hard pressed no such steady retreat will be possible, and then, concentrating where best it can, it must be prepared to fight boldly. The question is how far can artillery assist such a mobile force spread over so large an extent of country.

Its *rôle* is simple on the side of the victors, for, advancing and co-operating, as long as it can, with the cavalry, it will be employed in shelling outposts and preparing for attack.

But in case of retreat, especially if hurried, will it not impede the general movement?

This will, no doubt, depend upon the nature of the country. If the latter be perfectly open, artillery may even then be employed in considerable force with great advantage; but if it be close and difficult, it must either be left behind or be an impediment to the cavalry which remains to assist it. It must, then, be a mistake to attach a fixed number of batteries to cavalry so employed. They should rather be drawn, as required, from the corps artillery.

While advocating the necessity for the highest mobility obtainable, a limit must be acknowledged.

Artillery cannot, never can, hope to accompany cavalry everywhere. The statement of a writer in a recent number of a Service magazine, who speaks of our horse artillery as being equal to cavalry in "pace and power of surmounting obstacles," and of having seen it "at work, stopped by no obstacle, and taking ditches and banks as if they were riding across country after a fox," can only be regarded as misleading.

Horse artillery combined with large masses of cavalry.

The next war between two well-equipped and well-organized armies, employing covering cavalry as above, will throw much light on the subject; but in the meantime our object must be to provide ourselves with an artillery which will be likely to be most frequently of use.

The duties of artillery acting in combination with masses of cavalry have been laid down as follows:—

1. Covering the deployment of the cavalry and preparing the place for its attack.

2. Preventing the overthrown enemy from rallying.

3. Covering the retreat of its own cavalry, if unsuccessful.

While preserving considerable freedom of movement as to choice of position, it must be careful not to interfere with the deployment, advance, or retreat of the cavalry.

From a first position on the flank, if possible beyond the reach of musketry, but at decisive range (1000 to 1500 yards), it will open on the hostile troops, directing its fire on the immediate point of attack, and "regardless of the enemy's artillery fire from any other direction, and regardless of other dangers which it is the duty of the cavalry to ward off from it." *

* Hohenlohe.

It is impossible to lay down strict rules for its further guidance, as its subsequent movements must be regulated by circumstances, which must be taken advantage of by an able leader on the spur of the moment. Its main object is to support the attack to the last; and with regard to this point, it is a disputed question whether on its fire becoming masked by the advance of its cavalry, it should advance to a shorter range or "stand fast and operate against the enemy's artillery, against his flank attacks, and against his reserves." The latter is the opinion of Kraft, Prince of Hohenlohe, but, as before stated, its action must be regulated by circumstances, *e.g.*, the nature of the ground, whether favourable for rapid movement or not, the abundance or dearth of suitable positions, and whether it has been able to take up its first position at close range.

But, if a rule be laid down, we should say that a portion should advance in time to be in position before the fire of the remainder becomes masked, in order to afford that support which is essential up to the last, and the cessation of which for a moment might be fatal.

Moreover, thus echeloned, the batteries will be equally well prepared for either of the next phases of the action, to advance and complete the rout or to cover the retreat.

Occasions may occur when large masses of cavalry may be thus employed with advantage, but they will be few.

"It may be questioned if the charges of large masses of cavalry, as executed during the wars of the early part of this century, . . . can now be carried out." Its action on an actual battlefield must "now be generally limited to watching the flanks, checking the action of the hostile cavalry, attacking broken and repulsed infantry." *

But to the heads given above for the action of horse artillery and cavalry combined may be added a new one, viz., "Attacking the enemy's dispositions by means of artillery fire under the protection of cavalry." †

General *rôle* of H. artillery on the field of battle.

This will be the chief *rôle* on the actual battle-ground of the main army. And for its execution it is advocated that a certain number of batteries (according as the country affords facilities for their use) be retained in attendance on the heavier batteries, either out of action, or at all events in positions specially chosen with a view to future movement.

"Recent experience points out that it is not impossible to withdraw batteries from action, and move them, if required, to other parts of the field even under effective hostile fire." ‡

Thus placed, their duties will be, supported by cavalry, to follow up the work of the heavier batteries supporting attacks and counter-attacks at decisive ranges, to manœuvre against the enemy's artillery and other masses, and against his flanks, always obtaining when possible flanking fire.

This action will frequently necessitate great exposure, but, as Colonel

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* Home, 1873. † Colonel Smyth, Prize Essay, 1876.

‡ Captain Clayton, R.A., 1877.

Home says, in speaking of cavalry and horse artillery acting against an enemy's flanks, "it is requisite that they should be boldly used, and advantage taken of the rapidity of their movement; they must not be kept close to or hanging on the infantry for support, but must act boldly."

Acting thus, it will doubtless open out frequent opportunities for the charges of moderate or small masses of cavalry. "Important opportunities which recent tactics will afford to cavalry will be the attack upon masses of artillery." * Such cavalry will, moreover, protect it from attack, if not itself overthrown; but to guard against such an emergency a special support will be required, which will be considered under the head of Escort.

The duties of the escort will be :— Escorts

1. To guard the exposed flank when in motion or action.
2. To reconnoitre positions about to be taken up.
3. To support at the last moment in the event of attack.

The late Franco-German War has proved what guns, well worked, are capable of doing at close quarters.

But to work them to the last, their detachments should have that coolness which can only be afforded by the confidence that when they have obtained the greatest effect from their "fire," they have a support at hand ready to deliver that "shock" of which they themselves are incapable.

Artillery and cavalry, thus combined, possess an immense power; one arm is the complement of the other.

It has been said that, "as however cavalry is only an offensive arm, it is evident that it is only efficacious as an escort to defend the guns from an equal force of hostile cavalry." On the contrary, if the detachments work with coolness, and, commencing with shrapnel, follow on with case till the last moment, they will leave a large mass of opposing cavalry an easy prey to a comparatively small supporting body.

It has been proposed that a certain portion of the escort should act dismounted when thus supporting guns. But modern shrapnel is so searching that it will give artillery ample fire against troops even in open order, and it would therefore be a mistake to run the risk of rendering the escort unsteady by dismounting troopers, and thus diminish in any degree the power for shock which is required to complete the work.

Mounted riflemen would afford a still more mobile combination of fire and shock, which might often be most advantageously employed when the use of the above combination of artillery and cavalry would be out of the question. As a force attacking guns will generally attempt to act against the flank or rear, and will, when possible, direct a portion of its strength against the guns, and a portion against the support, it will be necessary to be prepared to throw a portion of the guns round and to divide the support accordingly.

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* Hamley, 1872.

The chief objections raised against attaching a permanent and special escort to artillery are:—

Firstly, that if the escort be of sufficient strength to be of real service, it will weaken too much the cavalry of the army.

But is not an exaggerated idea generally taken of what strength is sufficient?

As it has been endeavoured to show, if the artillery be properly handled, the escort need not be large.

Secondly, that cavalry will seldom be adapted to the ground.

But if the guns can reach the position so can the cavalry; and once there, they will probably find some point from which they can operate.

Moreover, the mere presence of even a few mounted swordsmen will give coolness to the gunners, and in this way alone be of great service.

The covering cavalry will either be driven in or will continue to advance till it meets the enemy in force. In either case the advanced guards will be called into play.

The advanced guard.

If it be intended to act on the offensive, the duties of the latter will be to cover the deployment of the main body.

Artillery will commence the action, and, if possible, both heavy and light batteries should be at once brought up.

The former will be most effective against the entrenchments and earthworks which the enemy will throw up, the latter will be best fitted for manœuvring to attack his general dispositions.

If a defensive attitude be determined on from choice or necessity, the duty of the advanced guard will be to contain the enemy and force his deployment while the main body prepares itself on the most favourable position. There will here be ample opportunity for the employment of horse artillery.

"When an advanced guard is powerful in artillery, the deployment of the enemy's infantry at a distance can probably best be forced by the temporary advance of a battery to the front supported by cavalry."*

"The lightest battery would of course be used." †

It will also be necessary to manœuvre against the vigorous attempts which will probably be made by the enemy to prevent the execution of the defences.

The offensive.

The first object of the attacking artillery should be to silence that of the enemy, the second to demoralize and break down the infantry.

Heavy batteries will be best suited for the first, while horse artillery should be held ready for instant movement; for, on the advance of the infantry, the fire from the original position will sooner or later become masked; it will then be necessary to advance some guns in good time to be in readiness to maintain, from shorter ranges, that artillery fire "which is essential up to the very end,"‡ and which must be carried on without a moment's interruption.

Only a portion of the guns can be brought into action in this second position, which will be less extensive.

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* Scherf. † Lieut. Pratt, R.A., Prize Essay, 1874.
‡ Clery, 1877.

Horse artillery then will be best employed on this service, while the heavier batteries are better able to carry on an effective fire from the longer range.

Sooner or later, according to circumstances, to be decided on the spot, *e.g.*, the effect already obtained on the enemy's guns, the fire must be turned on the infantry; then, supporting the attack to the last, these light batteries will hold themselves ready to advance and hold the position and complete the rout, or to cover the retreat and draw off the opposing fire in case of defeat.

Other horse artillery batteries must be employed to manœuvre against those counter-attacks which are "the life of the defence," against any attempt on the part of the enemy to advance guns to reach the attacking infantry when yet in column, to enfilade any portions of the defensive line which offer, and generally to act against the flanks.

The defensive.

On the defensive, every attempt must be made to destroy the enemy's batteries as they come into action, and before they bring up a sufficient number to establish a supremacy.

Horse artillery, acting from advanced and flanking positions, will be best adapted for this purpose, manœuvring against any batteries unduly exposing themselves coming into action or changing position, and against the enemy's masses.

Modern shrapnel will have a deadly effect against troops arriving within range in any close formation.

But the attacking bodies will specially avoid such an approach; their formations for attack should be assumed immediately the leading troops arrive within effective range of the enemy's artillery." *

Still there is no reason why horse artillery should not be advanced to reach them while still in column, when a few rounds would amply repay the risk run, and at least force an earlier deployment. These batteries should afterwards retire, as the attack advances, to previously prepared positions, and remain ready to open on the infantry at the critical moment of their assault.

Retreats and pursuits

The efforts of a rear-guard of a defeated and retreating army should be directed to delaying the pursuing force, to gain time for its own main body to retire, and to protecting the latter from attack, which results are best obtained by holding favourable positions as long as possible without compromising itself, and then withdrawing rapidly to a fresh position.

As such positions are not to be held permanently, a comparatively great extent of front may be covered, which will afford advantageous positions for cross-fire from artillery posted wide on the flanks.

As the utmost rapidity of movement is necessary, horse artillery must be employed, and as it will seldom be desirable to take the offensive, and, except occasionally, as when covering the passage of a defile, when a stand must be made, fighting at close quarters will rarely take place, it may be employed in large quantity.

"In pursuit the great aim should be to strike not the rear but the flank of the retreating enemy."

* Clery, 1877.

"Cavalry and horse artillery are best adapted for making circuits by which to cut in on the line of retreat." *

While endeavouring to lay down rules for general guidance, it must be remembered that "nearly every military regulation should be followed by the words 'according to the ground and according to circumstances.'" †

The amount of artillery which may be employed on different occasions, especially for manœuvre, will vary. It must then, as before remarked, be a mistake to attach a fixed number of batteries to any cavalry force, for while at one time even the allowance of one battery per brigade will only be an impediment, at another a much larger proportion may be advantageously employed.

Corps artillery.

They should then rather be drawn from the corps artillery as required. The latter should consist as far as possible of the most mobile batteries, for its duty is to act at any point where a reinforcement may be required. Take the case of a feint directed to distract the enemy's attention from the true point of attack.

Suppose, for example, that the advanced guard is ordered to contain the enemy while the main body prepares to strike a blow in quite a different direction. It is allowed that an attack must be prepared by a heavy artillery fire. Unless this course be followed little importance will be attached to the feint.

Indeed the very fact of massing batteries will indicate "business." The corps artillery will then in the above case be first required to support the advanced guard in engaging the enemy, and subsequently to reinforce that portion of the main attack which becomes most seriously engaged.

The degree of efficiency with which it will perform these duties will depend upon its mobility.

Range-finders.

Power of rapid motion, when necessary, not constant motion, is advocated. But at the same time it must be remembered that the introduction of the range-finder will modify the evil occasioned by the separation of masses and their changes of position. On the other hand, to depend upon it too much will often be to lose the chance of a few rounds on favourable opportunities. Horse artillery especially should be trained to judge the range by eye and from the burst of a common shell.

Artificial cover.

Again, horse artillery will not so frequently as the heavier batteries be able to cover itself with earthworks, and it is therefore especially desirable that it should be trained to make the most of natural cover.

Taking up positions.

Though the main position is chosen by the commanding officer, there will be a certain amount of selection open to each battery, and to each individual gun. To take advantage of it, the Nos. 1 should precede their guns and select the exact positions on which they are to be brought up. In so doing, they will also reconnoitre the ground over which the batteries are to advance, so as to ensure its being practicable, or rather so as to enable them to avoid that which is impracticable. It is needless to say that all this must be practised in peace time, if we expect efficiency in war from our officers and men.

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* Hamley, 1872. † Home.

How many of the former can correctly judge of, and make allowance for, the error in burst of a shrapnel shell? Certainly there are some who cannot, and no wonder, considering the hurried manner in which much of the annual practice is carried on, and the nature of the ranges generally used. Efficiency of officers and men.

How many of the latter, even in batteries where a fair amount of trouble is taken to instruct them, are able to lay a gun or bore a fuze quickly and correctly?

How many officers of the other branches of the service have any adequate idea of the power of modern artillery fire?

How many have even seen a shrapnel shell fired? Certainly a great number have not, and it is to be feared that they will learn their first lesson at great cost.

Let us see to these things while there is time.

ON THE

EMPLOYMENT OF FIELD ARTILLERY

IN CONNECTION WITH THE OTHER ARMS:

(*Being an Extract from the Austrian "Exerzir Reglement fur die Artillerie."*)

TRANSLATED BY

MAJOR BRANCKER, Royal Artillery,

AND PUBLISHED BY DESIRE OF THE DIRECTOR OF ARTILLERY.

Fundamental Principles.

Artillery owes its importance to the power of its fire, and to its capacity of bringing this fire to bear at ranges beyond those of the infantry. The aim should be to reap the full advantages of these qualities at the most important points of the line of battle. Artillery should act in complete concert with the other arms, and by its activity create for them the most favourable conditions of combat. The divisional artillery is an integral part of the infantry division, and can, consequently, only be withdrawn from it by express orders of superior authority.

The corps artillery is employed under the direct orders of the officer commanding the army corps, who has, however, the power of attaching the whole or part of it to any unit of his command. When it is desired to produce a decisive effect, as large a number of guns as possible must be simultaneously brought into action from a suitable position.

Artillery should consequently, as a rule, be employed in whole divisions of batteries *en masse*, and only in exceptional cases by single batteries. When no decisive result is aimed at, or when detaching guns with small mixed forces, a half-battery, or even a single gun, may suffice. It must, however, be taken into consideration that success at the decisive point may be endangered by dividing the artillery.

The greater part of the field artillery is now equipped with the 9^{cm} gun.

The light batteries which have been organised for the corps artillery are intended especially for operations which demand rapid movements, or to accompany troops over difficult ground.

The *rôle* of the horse artillery, which is likewise armed with the light guns, is evident from its being attached to the cavalry.

Position and Duties of Officers Commanding the Artillery, and of Officers Commanding Divisional Artilleries.

The officer commanding the artillery, and the officers commanding divisional artilleries, are under the orders of, and act as advisers to, the officer commanding the troops to which they are attached. That they may be in a position to make proposals with regard to their own arm, they must be kept acquainted with any intended as well as present operations, with all dispositions likely to affect their divisions, and, as far as possible, with the enemy's movements.

The officer commanding the artillery (officers commanding divisional artilleries) should accompany the officer commanding the troops during any reconnaissance of the enemy, or of the ground, to receive his orders for the artillery. He ought to grasp clearly the intentions of the officer commanding the troops, so that it may be unnecessary for that officer to do more than issue general directions relative to the employment of the guns. It is, however, the duty of the officers commanding artillery to make any suggestions that may occur to them for the disposition of their own arm.

All orders for the disposition of the artillery are issued by the officer commanding the troops to which it is attached.

The officers commanding the artillery (officers commanding divisional artilleries) are responsible that these orders are duly carried out.

They will, however, when orders from the officer commanding can no longer reach them or be sent for, exercise their own judgment, and dispose the divisions under their command in the way best calculated to carry out the general directions they may previously have received.

During a march, the officers commanding the artillery (officers commanding divisional artilleries) will, as a rule, remain with the staff of the officer commanding the troops, and give their whole attention to observing the general configuration of the ground, and what positions it offers for guns, in the event of an enemy being encountered. Positions deemed suitable for guns should be carefully reconnoitred or personally inspected; but the commanding officer of artillery, if this duty should entail a lengthened absence, should make provision for his being found if wanted.

Officers commanding divisional artilleries will assume personal command of their divisions as soon as these are in action.

The officer commanding the artillery attached to the corps will assume command as soon as the greater number of the batteries attached to the corps are in action for a common purpose.

Distribution of the Batteries during a March.

The artillery should be so placed in a column on the line of march, that it may be brought into action in the anticipated direction with as little delay as possible.

In the case of an infantry division moving to the front, its advance-guard should be provided with a due proportion of artillery, which should march in rear of the leading battalion; while the remainder of the divisional artillery follows in rear of the leading regiment of the main body,* or even, under some circumstances, of the leading battalion.

The whole divisional artillery may, however, at times, have to be attached to the vanguard.

The corps artillery must be attached either to the leading division, or to that one with which its subsequent employment seems likely to become of advantage.

In movements to the front it must march, as a rule, in rear of the leading brigade of the leading division, the whole of whose artillery in this case is available if required for the main body of the vanguard.

The principles laid down here must, however, not be considered as binding, but merely as guides when neither the formation of the ground nor other circumstances demand their being deviated from.

During retreats a strong force of artillery will be kept with the main body of the rear section of the rear-guard.

On flank marches, or marches made in several columns, the object in view and the condition of the available roads must determine how the artillery is to be distributed.

Under all circumstances, however, when distributing the guns, their safety must be ensured by avoiding positions which might expose them to the possibility of being called upon to come into action in self-defence.

Attack.

The main task for the artillery is, as heretofore, to support the advances of its own infantry. It should therefore not only break down the resistance of the infantry holding the objective point, and prevent it from making a stand behind any available cover, but also engage the enemy's artillery, which will in most cases have to be partially silenced, before the guns are directed against his infantry, or the decisive attack attempted.

To ensure this the entire artillery of the main body ought to be brought up at the very commencement of a battle, and all the guns brought into action at once.

Before, however, artillery can be brought into action, a general idea of the relative positions must be obtained by engaging with the vanguard, or if necessary even with part of the main body, thus securing space sufficient for the artillery to deploy.

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* An Austrian regiment consists of 5 battalions.

The artillery will commence the attack generally at long ranges—say 2250 metres (about 2500 yards). Meanwhile the main body deploys, but awaits the issue of the artillery action before making a decisive advance. For advances of this sort require in most cases, and especially where localities are to be attacked, to be prepared by an effective fire against the objective point, which may necessitate the guns having to be brought to close ranges.

When the infantry commence their decisive attack, a part of the batteries at least must accompany them in their advance, and from this time the artillery must direct its fire more especially on the enemy's infantry.

The artillery, when ordered to advance, ought as a rule to receive general directions as to what position the officer commanding the troops intends them to occupy next; while it is left to the officer commanding the artillery (officer commanding divisional artilleries) to assign to the divisions their individual positions and special tasks.

The officer commanding the artillery (officer commanding divisional artilleries) must, however, reconnoitre the ground and select new positions, as the battle affords opportunities.

To be in a position effectively to support the attack during its decisive moment, the artillery must accompany the infantry as near to the objective point as it is possible for it to do without needlessly exposing itself to losses from infantry fire.

When the infantry, during an attack, gets so near to the objective point that the artillery cannot continue to fire on it without danger to their own troops, it must direct its fire on the enemy's batteries, remaining, however, ready to ward off any flank attacks which may be directed against the attacking infantry.

If the enemy's position is taken, a part at least of the batteries must follow as quickly as possible into it, and assist in holding it, while the other part, remaining in the old position, forms the necessary support, in the event of the infantry being again driven out of the captured position. In the latter case the guns thus left for retreating bodies to rally on must remain in action to the very last moment possible, to give the troops time to re-form under their protection.

These guns, which have remained behind, must, in event of the infantry establishing themselves firmly in the captured position, be hurried up into it.

It is most advantageous to place the guns so as to take the routed enemy in flank, and thus prevent his being able to make a fresh stand.

A retreating enemy must be pursued by a rapid fire.

Defence.

The *rôle* of the artillery is to render the advance of an enemy a difficult undertaking by keeping the ground, over which he has to pass under an effective and where possible a flanking fire, and to oppose him from the first, while he is still gradually developing his attack, with the whole of its available strength.

The divisional batteries, as well as those attached to the corps artillery, must be employed within the assigned space, to carry out the given orders; the manner will depend upon the commanding officer, and the nature of the ground. The positions for the several batteries must be carefully selected within the allotted ground, and as far as they admit of, technically strengthened, and the ranges of the most important objects must be at once ascertained. As in most cases an enemy will have several directions at his disposal to attack from, the positions constructed for the batteries should admit of a large number of guns being concentrated, as required, at different points.

On the defensive, the batteries, as a rule, are placed in rear of the line held by the infantry; sometimes, however, the formation of the ground may necessitate their being brought up into it, or at any rate very near to it.

A part of the artillery should at once be placed so as to command the main approaches which under all circumstances, an enemy must make use of, while the other part should be held back at points possessing good communications with every part of the battlefield, until the intention of the enemy is sufficiently recognised.

The actual positions are however, as a rule, not to be taken up until it is intended to commence firing.

To enable the artillery to move to different parts of the line of battle, and to ensure easy access from the divisions to the ammunition parks, roads, where required, must be constructed.

Positions for batteries in rear of the main position should be selected, and easy communications between the two be secured.

The artillery must avoid opening fire too soon, and at unimportant objects, for this brings no adequate advantage with it, discovers to the enemy the positions of the guns, discloses the arrangements made for the defence, and points out prematurely what points offer cover for organizing the attack.

The artillery must, therefore not be allowed to open fire except by orders of the officer commanding the troops, or officer commanding the artillery (officers commanding divisional artillery).

On the defensive, as a rule, the artillery must concentrate its fire on the attacking troops. The enemy's infantry will, in most cases, not attempt a decisive attack in the face of an effective artillery fire, but will wait until it has been partially silenced by their own batteries. A mere artillery duel, as a rule, produces no tactical result, and ought consequently to be avoided; it may happen, however, that the attack, in these endeavours to weaken the artillery of the defence, forces the latter into one.

When, under such circumstances, a duel of this character has been created, and is proving itself so unfavourable to the artillery of the defence as to give reasons for fearing that it will have to succumb prematurely, it will be judicious, if the ground affords cover in close proximity, to withdraw the guns from the enemy's fire, and to save the remaining strength of the artillery of the defence for the moment when the enemy's infantry will be making its decisive advance. As soon as the attack has commenced, the artillery of the defence must

direct its fire entirely on the infantry, and maintain its positions in spite of all losses sustained from infantry fire. Under no circumstances should it limber up and retire before the decision of the combat.

Guns must not be moved to the rear except by orders of the officer commanding the troops, or officer commanding artillery (officers commanding divisional artilleries). Cases where single divisions* are forced to make slight changes of front to avoid flanking fire are exceptions.

An attacking enemy must be fired upon until he actually enters the battery; and the possibility of losing guns is no excuse for leaving a position.

If an enemy is repulsed, the artillery must, by directing its fire on such larger bodies of his troops as retain their formation, try and break down his power of resistance completely.

Breaking off an Engagement.

The officers commanding the artillery (officers commanding divisional artilleries) must be guided by the relative positions at the time, and by the directions they have received from the officer commanding the troops, in determining which division* is first to retire, and in what succession the others are to follow in echelon, and which is to remain with the rear-guard.

As a rule the division* least engaged will be at once directed to take up positions in rear, and facilitate the withdrawal of the troops out of fire by checking the enemy's pursuit.

The positions most suitable for this purpose are those in rear, and to the flank of the position about to be vacated.

Retirements must always be commenced at a walk; at an increased pace only under imminent danger, when the unmasking the positions already prepared in the rear becomes necessary.

Fights for Localities.

In an attack on localities (farmhouses, villages, woods), the *rôle* of the artillery, in most cases, is confined to supporting the infantry. The instances where an enemy can be induced to quit a locality by the fire of guns alone will be few.

As soon as the objective point has been indicated to the artillery, it must prepare for the attack of the infantry by destroying with its fire all impediments likely to waste their strength in trying to surmount them.

This preparatory artillery fire must, on the one hand, be continued long enough to give time for it to create a real effect, while, on the other, it must cease before it becomes dangerous to the advancing

* Three batteries.

infantry. To avoid the latter, the guns should be brought up as near to the objective point as the nature of the ground will allow of without risk to their own safety. Where they cannot be brought close at once, they will be obliged to change their position during the action. The moment the infantry has gained an entrance at the objective point the artillery must cease firing.

In street fighting, particularly where strong reduits exist, it may be necessary to bring guns into the interior of a place to gain entrance for the infantry into the reduits.

Guns intended for the defence of localities must not be placed in front, or in the interior of the same, but on the flanks, where they will be considerably more effective, and will not be taken if the place is lost.

In an attack on field works the artillery should damage the enemy's guns, and shake such of his troops as are not covered by gun-pits.

As here it will depend generally upon purely artillery considerations where the guns should be posted, the officer commanding the artillery must ascertain what spots are most suitable for the purpose, and propose them to the officer commanding the troops.

When firing shrapnel against field works, in order to obtain from it the full advantage, positions under 1125 metres (about 1235 yards), even though little exposed to infantry fire, ought, as a rule, to be avoided; while, on the other hand, the positions must not be far off, as the batteries will be masked too soon by the attacking infantry.

While getting the range, as well as during the artillery fire preparing for the infantry attack on the works, special care must be taken that the guns are accurately laid and the effect of each shot carefully observed. To cover the advance of the infantry the batteries will have to fire less deliberately, and continue firing as long as it is possible to do so without danger to their troops.

The artillery must not change positions while the infantry attack is being carried out, but remain prepared to oppose any counter-stroke of the enemy.

For the defence of fortified positions guns, as a rule, should not occupy cover thrown up for the infantry, but be placed either in the open or under special cover.

The Passage of a Defile during an Action.

In debouching from a defile during an advance, the artillery, when the nature of the defile admits of it, should take up an advantageous position on the flank, whence it may by its fire facilitate the debouching of the force.

No artillery should pass through the defile, except by orders of the officer commanding the troops, nor until the outlet is protected by troops deployed beyond, and then as quickly as possible.

On arriving on the farther side, the artillery must deploy considerably to the flank and in advance, and by a well-sustained fire endeavour to draw the enemy's fire away from the entrance of the defile, on itself.

The guns should be so placed as to make it impossible for the enemy to bring them and the defile at the same moment under fire.

In a retreat through a defile, the batteries nearest to the entrance should remain in action to the last, while the retreat commences from the flanks. The divisions* which are withdrawn first must, after passing the defile, take up positions suitable for firing into the defile, as well as on its mouth, and thus prevent the enemy from pursuing.

Employment of Artillery in Masses.

An artillery mass consists of any number of artillery bodies, which, whether separated by intervals or formed in one continuous line, are intended, under the direction of a single head, to concentrate their fire on the same object. Artillery masses must be formed where the fire of a single division of batteries is not sufficient, and where an efficient concentrated fire is required.

To use artillery in masses will therefore be of advantage for concentrating fire on the objective point when preparing for the infantry attack; against the most important and most dangerous lines of approach available to an assailant, against the mouth of a defile from which an enemy is attempting to debouch; against positions and localities favourable for an obstinate defence, or when an engagement is to be broken off, so as to ensure an orderly retreat from the battlefield.

It must be left to the officer commanding the troops to decide when the artillery is to be massed, with what object and in what position. He must consider how far the ground admits of this formation and favours its employment.

The command of a mass devolves upon the senior artillery officer, whose duty it is to provide that any directions he may have received are carried out by the divisions unitedly, or, failing special directions, that the divisions are concentrated to further the general plan adopted for the battle.

As soon as the object for which the several divisions were massed has been attained, the officer commanding the troops should order the divisional artilleries back to the troops to which they were previously attached.

To facilitate this, the officer commanding an artillery mass will, when forming it up, and afterwards when manœuvring it, guard against the batteries becoming unnecessarily mixed.

The Employment of Horse Artillery with the Larger Bodies of Cavalry.

Horse artillery must make full use of its mobility, and, coming into action suddenly and unexpectedly, distract the enemy's attention from the cavalry and draw his fire on itself; then, by thoroughly shaking his

* Three batteries.

troops with its fire, and hindering them from deploying, effectively prepare for the attack on them.

Hence horse artillery should be so placed in the column of march that it may readily move out and take up a position, frequently, and perhaps generally far out on the flank and in advance, from which a fire can be kept up for a considerable time, without interfering with the deploying of the cavalry or being itself masked by their advance. Flanking, though at times exposed, positions must generally be taken up, giving as they do the artillery the command of the battlefield, without the fear of its getting entangled in the cavalry mêlée

Under no circumstances should the artillery come into action in front of its cavalry, nor, as a rule, must it be divided.

The continually changing nature of a cavalry fight puts it out of the power of the officer commanding the artillery to await orders in every case; he will here, more than in any other position, be called upon to use his own judgment. And to be in a position to do this he must be perfectly cognisant with the intended operations, consequently he should not quit the side of the officer commanding the troops until his batteries are actually going to be brought into action.

When once the cavalry has commenced to attack, the time remaining for effective action of artillery is short, and if missed, irrecoverable. The artillery will, however, efficiently perform its part, if it succeeds in firing a few effective shots against the enemy's cavalry; which, however, should, if circumstances admit, be allowed to approach to within effective shrapnel range.

When no longer able to fire without endangering its cavalry, the artillery must limber up and await the course of events.

If the attack succeeds, the artillery must hurry forward and assist in the pursuit; should the attack prove unsuccessful, the guns must endeavour to gain a position from which they can check the enemy's pursuit.

In attacks of large bodies of cavalry on infantry, the artillery attached to the former must strive to get as near as possible to those detachments which, from their position, allow of a searching fire being brought against them, and these will then also become the object of the cavalry attack.

Escort for Artillery.

Officers commanding troops are ordered by the imperial regulations for the evolutions of cavalry to provide the artillery with suitable escorts, whenever necessary, and these regulations also detail the duties of officers in command of such escorts.

When artillery marches alone, an escort is always desirable.

Its strength, and the arm of which it is composed, must depend upon the particular duty upon which the artillery is to be employed, and upon the number of guns to be escorted; care, however, must be taken that the troops from which the escort is furnished be not unduly weakened; it follows, therefore, that in the course of an action an escort may be changed, or even withdrawn.

P

P C L M E C F S S P L V V E T F C

H C E M C V S

J T

APPENDIX.

A.

GENERAL ABSTRACT

OF THE

INCOME AND EXPENDITURE OF THE ROYAL ARTILLERY INSTITUTION,

From 1st April, 1877, to 31st March, 1878.

EXPENDITURE.

		£	s.	d.	£	s.	d.
Printing	Wages	193	15	9			
	Paper and Materials	327	11	7			
	Type and Furniture	63	13	2	722	9	6
	Wood Engraving	54	17	0			
	Lithography	82	12	0			
Photography					3	15	7
Classes					270	8	4
Lectures					21	15	0
Library, and Books for Sale					330	4	3
Museum					35	13	6
Instruments					22	16	0
Carpentry	Wages	19	5	8	98	2	4
	Materials	78	16	8			
Furniture and Repairs					120	10	0
Subscriptions to Societies					4	4	0
Stationery					122	8	5½
Postage and Parcels					95	14	3
Incidental Expenses					51	19	6½
Wages to Clerks and Orderlies					145	10	9
W.O. Photographs and Lithographs					4	7	6½
Balance of Sabine Portrait Fund					77	2	4
Transfer of Stock					1	16	6
Fire Insurance	R.A. Institution in £5000	12	10	0	13	18	6
	R.A. Observatory in £1000	1	8	6			
Cash in hand, 31st March, 1877	Of Secretary	4	19	3½	243	7	10½
	Of Messrs. Cox & Co...	238	8	7			
					£2386	4	3

INCOME.

		£	s.	d.	£	s.	d.
Cash in hand, 31st March, 1877					344	5	9
Printing					123	0	7
Photography					4	12	0
Classes					91	6	2
Books sold					240	5	10
Instruments					2	15	6
Carpentry					42	11	8
Subscriptions	Entrance	54	0	0	1262	6	0
	1872-3	0	16	0			
	1873-4	1	16	0			
	1874-5	4	0	0			
	1875-6	11	18	0			
	1876-7	26	11	0			
	1877-8	1152	18	0			
	1878-9	10	7	0			
Stationery sold					160	8	2
Postage and Parcels					53	9	9
W.O. Photographs and Lithographs					1	17	10
Dividends on £2000 Consols					59	5	0
					£2386	4	3

B.

Dr. DEBTOR AND CREDITOR ACCOUNT FOR THE YEAR ENDING 31st MARCH, 1878. Cr.

		£	s.	d.	£	s.	d.
Printing Materials and Wood Engraving					7	19	10
Classes for Drawing Instruction					35	14	0
Books and Periodicals					87	11	2
Museum					7	10	0
Carpentry and Picture Framing					5	16	8
W.O. Lithographs					0	11	10
Stationery					0	12	2
General Credit, 31st March, 1878					2550	0	8½
					£2695	16	4½

		£	s.	d.	£	s.	d.
Cash in hand, 31st March, 1878					243	7	10½
£2000 Consols Stock, at 95					1900	0	0
Value of Stock.	Printing Paper	55	6	6	118	4	9
	Books for Sale	11	5	6			
	Stationery for Sale	16	12	9			
	"Kane's Lists" (unbound)	15	0	0			
	Chemicals in Laboratory	20	0	0			
Owing by Members.	Printing	22	7	1	434	3	9
	Photography	3	15	8			
	Classes	31	17	0			
	Taxidermy	1	10	6			
	Books and Binding	71	2	0			
	Carpentry	16	8	7			
	Subscriptions	185	17	4			
	Stationery	52	2	11			
	Postage and Parcels	41	18	9			
	W.O. Photographs and Lithographs	7	3	11			
					£2695	16	4½

Examined and found correct,

J. DE HAVILLAND, Lt.-Col. R.A., and Colonel,

T. C. HIGGINSON, Major and Staff Paymr.

Woolwich, 30th April, 1878.

Cavalry should be employed for the protection of artillery when moving, while guns in position are better protected by infantry.

Half a squadron ought, as a rule, to be attached to the artillery of the cavalry to search the ground, and to protect it against the smaller detachments of the enemy.

Guns attached to small detachments require, usually, special and relatively large escorts, as the fronts of such detachments in action are too short to allow of the artillery being effectively employed in close proximity to them.

A stronger escort has frequently also to be attached to the artillery of the cavalry; its rapid action, and the unexpected direction it frequently takes, not giving time to make special arrangements for the protection of the guns.

The immediate duty of an escort is to protect the artillery. Both on the march and in battle it must therefore be stationed where danger is most to be expected, in a formation best suited for early discovering and effectually repulsing any attack.

An infantry escort ought as a rule to be stationed in front of, and a cavalry one in rear of, the exposed flank of the batteries, and the latter must secure them against surprise by throwing out vedettes.

Where guns are placed on the crests of heights whose slopes cannot be overlooked, part of the escort must ensconce itself in the dead angle to prevent the enemy creeping up there.

The flanks ought to be sufficiently watched to the rear to guard against a surprise of the wagons.

As soon as an attack directed against the guns is recognised as of a decisive character, the escort must take up the best position for meeting it.

When positions are being vacated, part of the escort should remain in them, after the guns are withdrawn, to keep off the pursuing skirmishers long enough for the artillery to get a start.

This detachment must retire on the flank of the artillery, so as to leave its line of fire free.

ANNUAL REPORT

AND

ABSTRACT OF PROCEEDINGS OF A GENERAL MEETING OF THE ROYAL ARTILLERY INSTITUTION, HELD ON JULY 1, 1878.

Lieut.-General Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., in the Chair.

1. The Committee of the Royal Artillery Institution beg to submit the Annual Report to the General Meeting of members.

2. There are now 1553 members of the Institution. (*Vide* Table, Appendix "C.") During the past year 57 officers have joined the Institution, against 34 casualties from deaths and withdrawals.

3. The financial condition of the Institution continues very satisfactory; the general credit amounting to £2550. This is less by about £120 than the general credit of last year; the difference being due to increased expenditure in the Printing Department, consequent upon the preparation of a new edition of the "Handbook for Field Service," and also to increased outlay in assistance to Classes at out-stations. It will be seen that the cash in hand at the end of the year amounted to about £243. A portion of this sum has been absorbed by payment for a turning lathe ordered in the year, but not delivered until after its expiration. The remainder the Committee propose to expend upon the improvement of the Library; a Sub-Committee having been formed to suggest scientific and professional works which it is desirable that it should contain.

4. The French and German Classes held in the Institution have been, as usual, taken full advantage of. Classes have also been held in Turkish, Russian, and Drawing. There have also been Classes at out-stations, assisted from the funds of the Institution, for the study of French, German, and Drawing.

5. The Committee have to lament the loss of one of the earliest, most constant, and most generous friends of this Institution, in the person of the late Major-General Frederick Marow Eardley-Wilmot—an original member, late Trustee, and one of the "two Subalterns" (the other being Lieut. Lefroy) to whom its origination is due. It was particularly by his influence and exertions that the present building was erected at the public expense in 1851-4, and provided on so liberal a scale with whatever is necessary for instructional purposes. Major-General Eardley-Wilmot took from the outset a large view of the place and functions of such an Institution at the head-quarters of the regiment. His personal services were always at command, and his straightforward advocacy, supported by the well-known manliness and purity of his character, contributed greatly in its earlier career to enlist confidence

and disarm the less or more open opposition which is usually offered to proposals whose drift and purpose is imperfectly understood.

6. The subject selected for the Prize Essay of the year was—

"The *Rôle* of Horse Artillery in a Campaign."

Lieut.-General Sir J. H. Lefroy, Col. Saunders, and Lieut.-Col. Whinyates, were good enough to act as Referees.

Eleven Essays were submitted for competition.

The report of the Referees is as follows:—

"The undersigned, having been selected by the Committee of the R. A. Institution as Judges, and having carefully perused the several Essays on 'The *Rôle* of Horse Artillery in a Campaign,' are agreed in the following award for the Gold Medal, viz.:—

"The Essay bearing the motto

'Taliessin is our fullest throat of song.'

"We recommend that a Silver Medal be awarded to the Essay bearing the motto

'The strength of field artillery is not to be estimated by the number of guns, &c.'

"We desire to make honorable mention of the three following Essays—viz., those bearing the mottoes

'Et celer et audax. 3.'

'Αιεν αριστευειν, &c.'

'La critique est aisée &c.'

"There are three Essays bearing the motto 'Et celer et audax,' which we have numbered respectively 1, 2, 3.

"J. H. LEFROY, Lieut.-General.
"W. B. SAUNDERS, Colonel R.H.A.
"F. T. WHINYATES, Lieut.-Col. R.H.A."

[On opening the sealed envelope bearing the motto "Taliessin, &c.," Lieut. J. K. Trotter was found to be the author of the Essay.

As regards the Essay recommended by the Referees for the silver medal, no means of ascertaining the author* exists; the Essay not having been accompanied by the sealed envelope containing his name. The meeting resolved, however, that the silver medal should be presented to the author as soon as he could be identified.

The three Essays honourably mentioned by the Referees were discovered to be by Lieut. E. R. Elles, Captains Ollivant and Rawes, respectively.]

7. The Committee have to acknowledge a very valuable present of Books, chiefly relating to Natural History, from Sir Edward Sabine. The present arrived at a particularly opportune moment, when the Committee were specially occupied upon the improvement of the Library, chiefly in the direction of Natural History and Science.

* The author has been since ascertained to be Lieut. Howie.

The Museum has been enriched by over 80 specimens of Birds, presented by Col. Cadell. The present is the more valuable consisting as it does of specimens required to complete certain families of birds; Col. Cadell having been supplied at his own request with a list of what was required for this purpose.

Other valuable presentations have also been made. For lists of them see Appendices "D" and "E."

8. The thanks of the Committee are due to Col. De Havilland and Major Higginson, for their careful audit of the Institution Accounts.

9. The following changes in the Committee have taken place during the year :—

Colonel G. T. Field.....	replaced	Lieut.-Col. A. H. King.
" H. T. FitzHugh	"	Colonel G. T. Field.
Major W. Kemmis	"	" C. W. Younghusband.
Capt. A. G. Yeatman-Biggs	"	Major M. F. Downes.
" H. W. L. Hime	"	Capt. R. P. Hare.
Lieut. J. S. Clarke	"	" W. E. Denison.

It will be the duty of the General Meeting to elect an officer to serve upon the Committee in place of Major Brancker, who has completed the period of 3 years.

The Committee for the current year will stand thus :—

PATRON AND PRESIDENT :

Field-Marshal H.R.H. the DUKE OF CAMBRIDGE, K.G.

VICE-PRESIDENTS :

The Lieut.-General Commanding the District.
The Inspector-General of Artillery.
The Director of Artillery and Stores.
The Deputy-Adjutant-General, R.A.

MEMBERS :

The Assistant Adjutant-General, R.A.
The Director of Artillery Studies.
The Assistant Adjutant-General, Woolwich.
The Secretary, Department of Director of Artillery and Stores.
Lieut.-General W. J. Smythe, F.R.S.
" Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S.

Colonel H. T. FitzHugh.
" W. G. Andrewes.
Lieut.-Colonel F. T. Whinyates.
" W. N. Waller.
" J. S. Stirling.
Major E. J. Ward-Ashton.
" J. E. Blackwell.
Major F. Duncan.
Capt. C. Jones.
" A. G. Yeatman-Biggs.
" E. Clayton.
Lieut. G. Mackinlay.
" A. Eardley-Wilmot.
" J. S. Clarke.

Lt.-Col. M. Le Fer Taylor, *Secretary and Treasurer.*

The Annual Report having been read to the meeting,

1. *Proposed by Lieut. Skinner, seconded by Major Brancker:—*

"That the Annual Report, as read, be adopted."

Put to the meeting and carried.

2. *Proposed by Lt.-Gen. Sir H. Lefroy, seconded by Colonel Woolsey:—*

"That a vote of thanks be presented to General Sir E. Sabine, for his very valuable present of books."

Put to the meeting and carried.

3. *Proposed by Lt.-Gen. Sir H. Lefroy, seconded by Lt.-Col. M. Taylor:—*

"That, in consideration of the constant and valuable services of Major Brancker, during the three years he has been a member of the Committee, he be requested to continue to attend its meetings, and assist it with his advice, during the remainder of his term of office in the Department of Artillery Studies, Rule V. notwithstanding."

Put to the meeting and carried.

C.

Statement showing Increase and Decrease of Members of the R.A. Institution during the year ending 31st March, 1878.

Ranks.	31st March, 1877.	Increase.			Total increase.	Decrease.				Total decrease.	31st March, 1878.
		Promotion.	Retirement.	New members.		Promotion.	Retirement.	Withdrawal.	Death.		
EFFECTIVE LIST.											
General and Regimental Field Officers	469	47	—	—	47	—	7	8	6	21	495
Captains	333	73	—	2	75	47	1	2	3	53	355
Lieutenants	525	—	—	51	51	73	—	1	4	78	498
Paymasters	7	—	—	1	1	—	—	1	—	1	7
Quarter-Masters	5	—	—	—	—	—	—	—	—	—	5
Riding-Masters	5	—	—	—	—	—	1	—	—	1	4
Surgeons-Major	2	—	—	—	—	—	—	1	—	1	1
Veterinary Surgeons	4	—	—	—	—	—	—	—	—	—	4
RETIRED LIST.											
General and Regimental Field Officers	81	—	7	—	7	—	—	1	1	2	86
Captains	36	—	2	—	2	—	—	2	—	2	36
Lieutenants	11	—	—	—	—	—	—	—	—	—	11
Surgeons-Major	6	—	—	—	—	—	—	—	—	—	6
Surgeons	1	—	—	—	—	—	—	—	—	—	1
Chaplains	1	—	—	—	—	—	—	—	—	—	1
HONORARY MEMBERS..	44	—	—	3	3	—	—	3	1	4	43
Totals ...	1530	120	9	57	186	120	9	19	15	163	1553

D.

Presentations to the Library, &c.

Annual Report of H.M.'s Inspectors of Explosives for the year ending 31st December, 1876 ...
The Circumstances attending an Accident which occurred in the Factory of the Schultze Gunpowder Company at Eyeworth, Hampshire, 12th November, 1877 .....
Report on the Circumstances attending the Destruction of a Floating Magazine moored on the River Thames, 30th June, 1877 .....
Report on the Circumstances relating to an Explosion of Dynamite, at Burnbank, near Hamilton, N.B., 19th June, 1876.....

} Major Majendie, R.A.

Report on the Preparations for, and Observations of, the Transit of Venus	
"Fors Clavigera" for April, May, June, July, August, September, October, November, and December, 1877; and January, February, and March, 1878	J. Ruskin, Esq., LL.D.
St. Mark's Rest. Parts I. and II.	
Mornings in Florence, VI.: The Shepherd's Tower Water for Manchester from Thirlmere	
Questions and Answers for Mounted Men and Drivers of Field Artillery	
The Conquests of Russia in Central Asia. (*Translation*)	Lieut. J. C. Dalton, R.H.A.
Questions and Answers for the use of N.C. Officers and Men of Batteries of Field Artillery armed with the 16-pr. M.L.R. Gun of 12 cwt.	
Report of Colonel Younghusband, F.R.S., Superintendent Royal Gun Factory, on his recent visit to Spezia, October, 1876, to witness the trial of the Armstrong 100-ton Gun	
Extracts from the Proceedings of the Director of Artillery. Vol. XIV., Part IV.; Vol. XV., Parts I., II., and III.	The Director of Artillery.
Treatise on the Construction of Ordnance. 1877	
The Ship and Coast Guns of the German Navy	
Experiments carried on in Russia in 1875, to determine the best position of Guns, both for the Attack and Defence of Fortresses. Translated by Capt. E. Bainbridge, R.A.	
Militia Officers' Manual, and Guide to Examination, by Major E. Lyons, R.A.	The Author.
Proceedings of the Institution of Mechanical Engineers, January, May, and August, 1877	The Council of the Society.
Proceedings of the United Service Institution of India. Vol. VI., Nos. 26, 27, 28, and 29	The Council of the Society.
Proceedings of the Zoological Society of London. Part II.	The Council of the Society.
Proceedings of the Institution of Civil Engineers. Vol. XLIX., 1876–7	The Council of the Society.
Proceedings of the Scientific Meetings of the Royal Geographical Society of London, 1877. Parts III. and IV.	The Council of the Society.
Proceedings of the Royal Geographical Society. Vol. XXII., No. 1	
Quarterly Journal of the Geological Society. Nos. 123 to 133, Vol. XXXIV.	Capt. H. W. Feilden, R.A.
Report on the Circumstances attending an Explosion of Gunpowder which occurred at 57 High Street, Deptford, 28th August, 1877	
Report on the Circumstances attending an Explosion in a Tunnel near Festiniog, 23rd August, 1877	Major A. Ford, R.A.
The Circumstances attending an Explosion of Gunpowder at Hose Tunnel, near Scalford, 14th October, 1876	

Greenwich Magnetical and Meteorological Observations, 1875	Astronomer Royal.
Report of the Astronomer Royal to the Board of Visitors to the Royal Observatory, Greenwich	
Planschverk öfver Antagna Myare Gevärsmodeller Oscar II.	Norwegian Government.
The Archæological Collection of the United States National Museum	Smithsonian Institution.
The Exploration of the Aboriginal Remains of Tennessc	
Annual Report of the Board of Regents of the Smithsonian Institution, 1876.	
United States Geological Survey of Territories. Vols. VII. and VIII. Ethnography	U. S. Government, through Smithsonian Institution.
United States Geological Survey. "Fur-bearing Animals." Mis. Pub. VIII., 1878	
United States Geological and Geographical Survey of Colarado and adjacent Territory	
United States Arctic Expedition, Steamer "Polaris," C. F. Hall, Commander. Vol. I. Physical Observations, by Emil Bessels.	
Journal of the Royal United Service Institution. Nos. 89, 90, 91, 92, and 93, Vol. XXI.	The Council of the Society.
Washington Astronomical and Meteorological Observations	Rear-Admiral Davis, U.S. Navy.
Royal Engineer Prize Essay, 1876	R.E. Institute, Chatham.
Turkey in Asia, and Turkey in Europe. Maps...	
Occasional Papers Royal Engineer Institute. Nos. 1, 2, and 3, 1876; and Nos. 1, 2, 3, and 4, Vol. I.	
Two Maps, Seat of War in the East	
Bulletin de la Societe de Geographie, D'Anvers. Tome I.	Major F. Duncan, R.A.
The English in Spain	
Hart's Quarterly Army List for January, April, July, and October, 1877	R.A. Library, Woolwich.
Netherlands Artillery Atlas, Nos. 100, 102–105	Netherlands Minister.
Annual Report on the Instruction carried on at the School of Musketry, Hythe, and the Progress of Musketry Instruction in the Army during the Year ended 31st March, 1876	Commdt. School of Musketry.
Catalogo de Los Objetos Que Contene el Real Museo Militar a Cargo del Cuerpo D'Artilleria	A. G. Greenhill, Esq., M.A.
Military Dictionary. By Maj.-Gen. Voyle, R.A.	The Author.
Catalogue of the Special Loan Collection of Scientific Apparatus at the South Kensington Museum, 1876. 3rd Edition	Committee of Council.
Abstract of Meteorological Observations made at the Gardens of the Royal Botanic Society, Regents Park, London, 1871–76	The Council of the Society.
Dominion of Canada Artillery Association Prize Essay, 1876.	Lt.-Col. Strange, R.A.
Third Report of the Director-General of Military Education	D.-A.-General, R.A.
Field Artillery Exercises, 1876	

On a Circumstance affecting the Piling-up of Volcanic Cones	R. Malet, Esq., F.R.S., F.G.S.
Austrian Government Map, No. 11, Widin; No. 12, Sofia	Qr.-Mr.-General.
Portrait (crayon) of the late Major-General Eardley-Wilmot, R.A., taken in 1839	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G.
Water-Color Sketch among the Ruins of Palenque, Central America. Latitude 17½° Long. 92°. By J. H. Caddy, R.A., about 1835	
Annual Report of the Department of the Interior, for the year ended 30th June, 1874	
Report of the Surveys and Preliminary Operations on the Canadian Pacific Railways, to January 1878	
Report on the State of the Militia of the Dominion of Canada, for the year 1877	Lt.-Col. Irwin, R.A.
The Principles of a New System of Sighting Ordnance, dispensing with all Calculations in Gunnery Practice as applied to Telescopes and the Service Sights of the present day	Capt. L. Scott, R.E.
Lecture on the above Subject at the Royal United Service Institution	
Progress Report of the Committee on Explosives	The Secretary of State for War.
Franco-German War, 1870–1. Part II. 10th Section	
Correspondence respecting the Rights and Privileges of the Latin and Greek Churches in Turkey. I. to XVIII., except Part XIII.	
General Index to Bills, Reports, Estimates, &c., 1852–3, 1868–9	
Russo-Turkish War. Operations in Asia, 1877, 17th May to 18th November	
Map of Turkey in Europe. 4 sheets	
Map, Sheet I., Servia. Turkey in Europe	
Notes on Ammunition, 1877. 4th Edition	
Sheet VI., Map of Roumelia and Bulgaria. Scale $\frac{1}{422000}$	
The Armed Strength of France	
Reports on the Philadelphia Exhibition of 1876. Plans.	Col. Sir H. B. Sandford.
International Exhibition, Philadelphia, British Sec. Catalogue	
Royal Philadelphia Exhibition, 1876. Vols. I. and II.	

Books, &c., purchased.

A Monograph of the Family of Hornbills. By D. G. Elliott, F.R.S.E. Parts I., II., III., and IV.

Report of the Committee to enquire into certain questions that have arisen with respect to the Militia and the present Brigade System.

The German Field Artillery Matériel of the year 1873. By R. Willie.

A Lexicon of the English and Turkish Languages.

Map of Armenia and Kurdistan, in 8 sheets. By Dr. Kiepfer.
Map of European Turkey, in 20 sheets. By Handtke.
Map of Caucasian Isthmus and Armenia, in 6 sheets. By D. Koch.
The Ibis. Vol. I., Nos. 2, 3, 4, and 5.
Influence of Firearms upon Tactics. Translated by Capt. E. H. Wickham, R.A.
Gould's Birds of Asia. Parts XXIX. and XXX.
Military Bridges. By Sir Howard Douglas.
Birds of Europe. Parts LVII. to LXVI.
Jahresberichte über die Verander ungen und Fortschritte im Militairwesen.
Campagnes des Russes. 2 vols. and atlas.
4 copies of Pocket Book for Field Service. By Major-General Sir G. Wolseley. 3rd Edition.
Encyclopædia Britannica, Ninth Edition, Vols. VI. and VII.
Text-Book of Science: Electro-Metallurgy. Gore.
The Officer's Memorandum Book.
The Family of Sun-Birds. Parts IV., V., and VI. By Capt. Shelley, F.Z.S.
Arundel Society Plates:—
1. "Christ Bearing the Cross."
2. "The Angel Gabriel and the Virgin Annunciate." By Hans Hemling.
Sixth Report of the Royal Commission on Historical Manuscripts.
Zum Spreng-geschoss Feuer der Land-und-See Artillerie.
The Winds. By W. L. Jordan.
The Elements of Field Artillery. By Capt. H. Knollys, R.A.
Studies in Troop-Leading. Parts III. and IV.
Campaign 1870–1. The Operations of the First Army under Gen. Von Steinmetz. Capt. E. O. Hollist, R.A.
Tactical Studies of the Battles of Columbey-Nouilly.
Taktik der Feld-Artillerie. E. Hoffbauer.
Army Report (Royal Artillery and Royal Engineer Officers' Arrears of Pay.)
Manual de l'Artilleur en Campagne.
Military Labour Schedule. By F. W. Edwards, M.F.W.
The Elements of Military Administration and Military Law. By Capt. Boughey.
O'Byrnes Collection of Army Circulars and General Orders, with Indices, &c., 1867–1876.
Tactical Examples, "The Battalion." Translated by Col. Sir Lumley Graham.
Weighing and Measuring. By H. W. Chisholm.
Text-Book of Fortification and Military Engineering. Part I.
History of Cavalry. By Col. Denison.
Further Correspondence respecting the Affairs of Turkey. Nos. 1 and 2, 1878.
Jamieson's Code and Appendices.
The Sailor's Pocket-Book.
Watts' Dictionary of Chemistry. 7 vols.

E.

Presentations to Museum.

Bird Skins:— Herring Gull, Bittern, Green Heron, Kildeer Plover, Bartram's Sandpiper, Cardinal Red-Bird	Capt. R. D. E. Lockhart, R.A.

Grass Shoes from Chumba, India	Major R. C. Smith, R.A.
2 Pair Bark Shoes from Chumba State	
1 Pair British Lahoul Grass Shoes	
Argus Pheasant	W. Davidson, Esq.
Peacock Tail	
2 Small Rhinoceros Horns	
1 Goiur Horn	
1 Buffalo Horn	
1 Snout of Sword Fish	
2 Birds (Burmah)	
A Small Collection of Minerals and Shells	Col. E. J. Bruce, R.A.
Pair of Trousers given to Capt. Biddulph by the "Atalik Ghazee"	Col. R. Biddulph, C.B., R.A.
Pair of Boots and 2 Pairs of Slippers worn by the Women of Eastern Turkistan	
Snow Shoes worn by Doctor Rae in his Franklyn Search	Capt. H. W. Feilden, R.A.
Greenlander's Harpoon	
Frigate Bird from Ascension (*Atagau Aquillus*)	Mr. Whitely.
Russian Carbine taken at the Action of the Bulganac, 19th Sept. 1854, from a dead Russian Cavalry Soldier	Surgeon-Major Parry, R.A.
2 Eggs, Sandgrouse (Madras)	Capt. Desborough, R.A.
Skull of an Andaman Islander	Lieut. Parsons, R.A.
Pair of Chinese Shoes	Lt.-Col. O. H. A. Nicolls, R.A.
2 Chinese Padlocks	
A String of Chinese Cash, 1000 to the tael (6s.)	
Chinese Pack of Cards	
Russian Pack of Cards	
Swedish Copper Coin	Capt. Sladen, R.A.

Birds from India, presented by Colonel R. Cadell, R.A.

	No.
Micronisus badius	2
Halcyon leucocephalus	1
" fuscus	1
Alcedo bengalensis	2
Hydrocissa coronata	1
Palæornis torquatus	2
" rosa	2
" columboides	1
Picus mahrattensis	1
Chrysocolaptes sultaneus	1
Megalaima viridis	2
Coccystes melanoleucos	2
" coromandus	1
Centropus rufipennis	1
Dendrophila frontalis	2
Lanius erythronotus	1
Graucalus macei	2
Pericrocotus flammeus	2
Artamus fuscus	1
Leucocerca pectoralis	1
Eumyias albicaudata	2
Cyornis rubeculoides	2
Orocetes cinclorhynchus	1
Merula simillima	2
Pomatorhinus horsfieldii	2
Trochalopteron cachinnans	2
Criniger ictericus	2
Phyllornis malabaricus	2

	No.
Zosterops palpebrosus	2
Parus cinereus	2
Machlolophus jerdonii	1
Osmotreron bicincta	1
Columba intermedia	2
Galloperdix lunulosus	2
Perdicula asiatica	1
" erythrorhyncha	1
Coturnix coromandelica	2
Turnix taigoor	1
Cursorius coromandelicus	1
Rhynchæa bengalensis	2
Hydrophasianus chirurgus	2
Porphyrio poliocephalus	2
Anser indicus	1
Plotus melanogaster	2
Harpactes hodgsonii	1
Halcyon pileata	1
Palæornis bengalensis	1
" melanorhynchus	2
Chibia hottentota	1
Myiophonus horsfieldii	1
Garrulax leucolophus	1
Criniger ictericus	1
Oriolus chinensis	1
" melanocephalus	1
Ceriornis satyrus	1

List of Papers published in the "Proceedings" during the year.

The New Austrian Field Guns. By Captain J. F. Owen, R.A. (Captain Instructor Royal Gun Factories.)

Principles of Gunnery. Rifled Ordnance. By Captain J. Sladen, R.A. (Professor of Artillery, R.M. Academy, Woolwich). Chapters I. to VI.

Krupp's Patent Protected Non-Recoil System. Contributed by Major E. Maitland, R.A.

Account of an Expedition up the Bolan Pass to Khelat Territory, with Major Sandeman, Political Agent. By Captain H. G. Young, R.A. (Commandant No. 2 Mountain Battery, Bombay Presidency.) Part II.; Major Sandeman's Mission to Khelat.

Annual Report and Abstract of Proceedings of a General Meeting of the Royal Artillery Institution, held on May 24, 1877. Major-Gen. C. L. D'Aguilar, C.B., R.A., in the chair.

Composition and Strength of a Siege Train required for the Attack of a Modern Fortress. By Major W. Kemmis, R.A. (The R.A. Institution Prize Essay of 1877.)

Method of Arming Cliff End Battery, Isle of Wight, by Hauling the Guns up an Inclined Tramway. By Captain W. R. Rudge, R.A.

On the Attack and Defence of a Position. By Captain E. Clayton, R.A.

Raising 38-ton Gun from Mud. Diary of Operations. By Capt. H. Soames, R.A.

The Composition and Strength of a Siege Train required for the Attack of a Modern Fortress. By Colonel E. Wray, C.B., R.A.

Experiments made in Russia with the "Le Boulengé" Telemeter. Translated from the Spanish by Lieut. J. C. Dalton, R.H.A.

Shrapnel Fire. By Major S. J. Nicholson, R.H.A.

Historical Notices of the Royal Artillery. (No. II.) By Major F. Duncan, LL.D., &c., Royal Artillery.

Extract from Report on the Belgian Siege and Garrison Artillery. By Major and Bt.-Lt.-Col. H. Brackenbury, R.A., dated 9th September, 1876. (Communicated by the Deputy-Adjutant-General, R.A.)

Extract from Report on the Belgian Field Artillery. By Major and Bt.-Lt.-Col. H. Brackenbury, R.A., dated 16th October, 1876. (Communicated by the Deputy-Adjutant-General, R.A.)

Notes on the Field Artillery of Italy. Translated from the Spanish by Lieut. J. C. Dalton, R.H.A.

Limbers and Wagons. By Major W. B. E. Ellis, R.A.

On the Classification of Batteries of Field Artillery by Order of Merit in Shooting. By Capt. Hime, R.A., F.S.S.

Occasional Note. By Capt. Hime, R.A.

Results of Experiments made in the Royal Carriage Department (July 1877) to ascertain the Relative Value, in point of Traction, of the Service, or Service-Modified, and the Madras Field Wheels and Axles. Communicated by Major W. Kemmis, R.A.

Historical Notices of the Royal Artillery. (No. III.) By Major F. Duncan, LL.D., &c., Royal Artillery.

Rocket Shells, and Artillery of the Future. By Lieut. E. N. Henriques, R.A.

Translation from the French concerning a new form of Carriage for Field Ordnance firing Heavy Charges, with its application to proposed Field Guns for our own Service. By Lieut. Goold-Adams, R.A.

PRINCIPLES OF GUNNERY.

RIFLED ORDNANCE.

BY

CAPTAIN J. SLADEN, R.A.

PROFESSOR OF ARTILLERY, R.M. ACADEMY, WOOLWICH.

(*Continued from p. 284.*)

CHAPTER VII.

Drift of Elongated Projectiles.

Rotation round the Longer Axis of a Projectile.—Method of giving Rotation in Service Ordnance.—Circumstances which Determine the Velocity of Rotation required to keep a Projectile Steady in Flight.—Effect of Non-Centring.—Effect of the Resistance of the Air.—Position of the Centre of Gravity.—Length of the Projectile.—Distribution of the Mass of the Projectile.—The Spiral Motion of an Elongated Projectile.—Illustrated by means of a Gyroscope.—Drift of an Ogival-Headed Projectile.—Drift of a Flat-Headed Projectile.—Varying Conditions which affect the Drift.—Practical Conclusions.

Rotation round the longer axis of a projectile.

It has already been stated (Chap. I. p. 26) that sufficient rotation is usually given to an elongated projectile round its longer axis to keep it *as nearly as possible* point first, or, in other words, in the direction of the tangent to the trajectory, during flight.

It is well known that if a service elongated projectile were fired with no rotation round its longer axis, it would oscillate about its shorter axis through the centre of gravity, and tend to set its longer axis at right angles to the direction of motion.

Method of giving rotation in service ordnance.

Rotation is given in service ordnance in three ways:—

(1) By means of a soft metal *coating* on the cylindrical surface of the projectile (slightly larger than the diameter of the bore) being forced into the spiral grooves of the bore; as in the Armstrong B.L. guns.

(2) By means of *studs* on the projectiles fitting the spiral grooves of the bore; as in the French and Woolwich systems of rifling.

(3) By means of a metal *disc* attached to the base of the projectile, and expanded into the spiral grooves of the bore by the impulse on firing; as in the more recent ordnance with polygroove rifling.

Circumstances which determine the velocity of rotation required to keep a projectile steady in flight.

The velocity of rotation required to keep a projectile steady in flight depends—

(1) On the centring, or otherwise, of the projectile as it leaves the bore.

(2) On the effect of the resistance of the air which the projectile meets with, tending to give it rotation round its shorter axis.

(3) On the position of the centre of gravity of the projectile.

(4) On the length of the projectile in calibres.

(5) On the distribution of the mass of the projectile.

Effect of non-centring.

If the projectile is centred as it leaves the bore, there will be no force tending to cause rotation round its shorter axis until gravity deflects the trajectory from the line of departure, and in this case the force is gradually applied, and in a constant direction, producing similar steady gyration; but if the projectile be not centred, there will be at once on leaving the bore a force causing rotation round its shorter axis, acting in an uncertain direction, and producing dissimilar unsteady gyration.* In order to keep the semi-amplitude of the gyration small, it is necessary to give a higher velocity of rotation than would have been required if the projectile had been centred; so that the axis of the projectile may be kept as nearly as possible in the direction of motion of the centre of gravity of the projectile, or, in other words, tangential to the trajectory. If the velocity of rotation is not sufficient, the semi-amplitude of the gyration will increase, and the projectile becomes unsteady, and wabbles in flight. In extreme cases the projectile will turn over; as, for instance, in long shell when fired with a low velocity.

Effect of the resistance of the air.

The effect of the resistance of the air, and the point of application of that resistance on projectiles of different shapes, will next be considered.

Fig. 1.

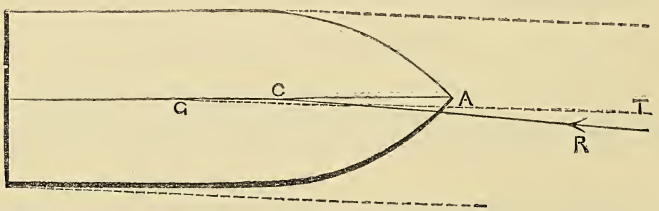

Fig. 1 represents a vertical projection of an ogival-headed projectile, *G* the position of its centre of gravity in its longer axis, *GA*. The direction of motion of the projectile is represented by *GT*, being a tangent to the trajectory, which has dipped from the line of departure, which if the projectile is centred is coincident at the muzzle with the axis of the projectile, *GA*.

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* Gyration must be understood to mean the rotation of the axis of the projectile itself round the trajectory described by its centre of gravity. The semi-amplitude of the gyration is the angle which the axis of the projectile makes with the tangent to the trajectory at that point.

The front part of the projectile is, then, meeting the air in directions parallel to *GT*. The resultant of the resistance of the air opposed to this motion does not usually (owing to the form of head) act in exactly the opposite direction, but in a direction inclined to it, as *RC*. The point *C*, where the direction of the resultant of the resistance intersects the axis of the projectile, is called the "centre of resistance." The resultant *R* acts in the direction *RC* in the plane passing through the axis of the projectile and the tangent to the trajectory.

The resultant, *R*, acting at *C* may be replaced by an equivalent force, *R*, acting at *G*, the centre of gravity of the projectile, and parallel to *RC*, and a couple whose moment is proportional to $R \times GC$. The tendency of the couple, as drawn in Fig. 1 (which represents the case of an ogival-headed projectile) is to *raise the point of the projectile—i.e.*, to give the projectile rotation round its shorter axis passing through its centre of gravity, and perpendicular to its longer axis.

The combination of this rotation and the rotation impressed on the projectile round its longer axis by the spiral grooves in the bore, gives rise to the gyration of the axis of the projectile round a tangent to its trajectory. If the moment of this couple is increased from any cause, the velocity of rotation of the projectile must also be proportionally increased, in order to keep the axis of the projectile as close to the trajectory as possible; or, in other words, to keep the semi-amplitude of the gyration within moderate limits.

The magnitude of the resultant resistance for a projectile of given diameter depends principally on the velocity and form of head of the projectile. Hence, when a projectile is fired with a high muzzle velocity, since the moment about the centre of gravity increases with the magnitude of the resultant resistance, a higher velocity of rotation is required to keep it steady under similar circumstances.

Flat-headed projectiles, for the same reason, require a higher velocity of rotation than ogival-headed projectiles.* In experiments made by Colonel Owen, R.A., "on the derivation of elongated projectiles," it was found "that the velocity of rotation given by the rifled B.L. 40-pr. was not sufficiently high to keep a flat-headed shot steady during flight, except at very short ranges."†

Position of the centre of gravity.

The moment of the couple tending to produce rotation round the shorter axis, depends on the relative position of the centre of gravity and the centre of resistance—*i.e.*, on the distance *GC*, in Fig. 1. The greater this distance is, the greater will be the tendency to upset the projectile, and the greater must be the *velocity of rotation*, in order to keep the projectile steady in flight. If the centre of gravity of the projectile were purposely brought towards the base, the tendency of the projectile would be to fly base foremost, unless it were counteracted by a much greater velocity of rotation than would be necessary under

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* The coefficient of resistance of flat-headed shot is much greater than for the ogival head (*vide* p. 241). For flat-headed shot, $K = 139{\cdot}6$.

† *Vide* Owen's "Modern Artillery," p. 245.

service conditions. If, on the contrary, the centre of gravity is towards the head, this distance is smaller, and a lower velocity of rotation suffices to keep the projectile steady in flight; for instance, in the Snider bullet the centre of gravity is more towards the head than it would be if the bullet were solid, and the very low velocity of rotation imparted to it ensures tolerable accuracy of fire.

Length of the projectile.

Generally speaking, the longer a projectile is in calibres for a given weight, the greater will be the velocity of rotation required to keep its axis close to the trajectory; because the resultant of the resistance usually acts with a greater leverage—*i.e.*, the moment of the couple tending to produce rotation is increased as the length of the projectile is increased. But it is quite possible, with some shapes of head and positions of centre of gravity, for the moment of the couple to be less with a longer projectile than with a shorter one of the same weight. In that case a greater velocity of rotation may be dispensed with. The principle to be remembered in considering the velocity of rotation to be given to an elongated projectile in order to keep it steady in flight is this—that the *velocity of rotation must be increased proportionately to the moment of the resultant resistance about the centre of gravity tending to rotate the projectile round its shorter axis.*

Distribution of the mass of the projectile.

The rate of loss of velocity of rotation owing to the resistance of the air depends on the distribution of the mass of the projectile. The velocity of rotation is maintained longer in the case of an elongated shell than in that of an elongated shot of given weight. Hence it is found in practice that an elongated shell is steadier in flight than an elongated shot of the same weight; the reason being that the radius of gyration is longer in the shell, and for a given velocity of rotation the energy of rotation is greater. (*Vide* p. 40.)

The spiral motion of an elongated projectile.

The direction of the rotation given to all service elongated projectiles is "right-handed"—*i.e.*, the upper part turns from left to right, with reference to an observer placed behind the gun. If the projectile is accurately centred, there will be no tendency to gyrate until gravity deflects the trajectory from the line of departure, and the direction of motion of the projectile ceases to be coincident with its axis. When this is the case, the resultant of the resistance of the air acts as in Fig. 1, tending (as explained before) to raise the point of the projectile, and to give it rotation round the shorter axis through the centre of gravity.* The combination of these rotations, in obedience to a well-known law in Mechanics, causes the axis of the projectile to gyrate in a right-handed direction; and the resistance of the air acting on the left side of the projectile drives the projectile itself bodily towards the right.

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* *Vide* a paper by Major Morgan, R.A., on the "Rifling for Heavy Guns," read at the United Service Institution on May 19th, 1873; also a paper by General Mayevski in the "Revue de Technologie Militaire," Tome V. p. 13.

The number of gyrations depends upon the velocity of the projectile: a projectile fired with a high velocity will make several gyrations, while a projectile fired with only a low velocity and at a high angle of elevation would only make a part of one gyration.

Fig. 2.

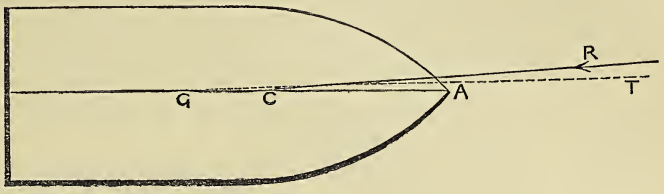

Fig. 2 represents a horizontal projection of an ogival-headed projectile at the end of the first quarter-revolution of its axis round the tangent to the trajectory—*i.e.*, during the first quarter of gyration. *G* represents the position of the centre of gravity in its longer axis, *GA*. The direction of motion of the projectile in the horizontal plane is represented by *GT*. The axis, *GA*, of the projectile is deflected to the right of this line. *RC* represents the direction of the resultant of the resistance of the air. The resolved part of this resultant resistance perpendicular to *GT* *causes the projectile itself to drift bodily to the right;* it also tends to rotate the projectile round its shorter axis through the centre of gravity, *G*. The combination of this rotation with the rotation impressed on the projectile round its longer axis causes the axis of the projectile to dip, and thus to commence the second quarter-gyration. Fig. 2, then, represents a *vertical* projection at the end of the second quarter of gyration.

The resolved part of the resultant resistance perpendicular to *GT* now drives the projectile bodily downwards, and at the same time tends to produce rotation by deflecting the axis of the projectile from the direction of motion. This rotation, combined with the rotation of the projectile, causes the axis of the projectile to deflect to the *left* (Fig. 1 may now be taken as the horizontal projection under these conditions); and the resolved part of the resultant in the third quarter of gyration drives the projectile bodily to the *left*, and tends to cause rotation, which, combined with the rotation of the projectile, causes the axis of the projectile to rise, and thus to commence the fourth quarter of gyration.

Illustrated by means of a gyroscope.

A gyroscope, with an elongated shot with a rounded head, serves to explain this motion. If the elongated shot is made to rotate in the direction of the hands of a clock—*i.e.*, with a right-handed rotation—and a pressure applied by means of a pencil-point on the head of the shot below its axis, then the axis of the shot will deflect to the right, with reference to an observer looking at it from the rear. If now the pressure is applied on the left front, the axis of the shot will dip; if

the pressure is applied on the head *above* the axis, the axis of the shot will deflect to the *left;* and finally, to complete the gyration, if the pressure is applied on the right front, the axis of the shot will rise. The pressure of the pencil-point corresponds with the direction of the resultant of the resistance of the air in the four quarters of gyration.

Drift of an ogival-headed projectile.

It will be seen that when the projectile is in motion and in the first and second quarters of gyration, it is driven to the *right,* and in the third and fourth quarters of gyration the projectile is driven to the *left,* by the resistance of the air; but as the time taken in the first and second quarters of gyration is longer than that taken in the third and fourth quarters,* the drift or derivation of the projectile is on the whole to the *right* of the plane of departure.

If *left*-handed rotation is impressed on the shot in the gyroscope, gyration under similar conditions will take place in the opposite direction, the axis of the shot first deflecting to the left.

If a projectile has left-handed rotation impressed upon it, gyration takes place in the opposite direction, and the drift will be in the first and second quarters of gyration to the left of the plane of departure, and in the third and fourth to the right; but as the time taken in the first and second quarters of gyration is longer than in the third and fourth quarters of gyration, the drift on the whole will be to the *left.*

In the above description of the spiral motion of an elongated ogival-headed projectile, the projectile has been supposed to be centred; but if this should not be the case gyration commences at once, and in an uncertain direction, and the axis of the projectile will be deflected at once, according to the position of the point on which the resultant of the resistance of the air acts on the projectile, and the projectile itself driven bodily in the same direction. Hence the shooting of guns in which the centring of the projectile is not secured cannot be relied upon for such accuracy as those guns in which the projectile is centred, because the drift cannot be so accurately allowed for.

Since the use of copper gas-checks in the 12·5-in. M.L. gun of 38 tons, the projectile has been centred, and the mean drift to the right for a given range has increased, and the shooting has been more accurate.

Drift of a flat-headed projectile.

The drift of flat-headed projectiles is not so marked as that of ogival-headed projectiles, and owing to the higher velocity of rotation required to keep flat-headed projectiles steady in flight, there is a difficulty in obtaining reliable experiments with flat-headed projectiles with service guns. Colonel Owen, R.A., made some experiments at Shoeburyness, in 1864, with flat-headed and cylindro-conoidal-headed shot fired from the Armstrong B.L. gun;† and the conclusion drawn from them is

* It may be noticed, also, that the resistance which drifts the projectile from the direction of motion is greater during the first and second quarters of gyration than during the third and fourth quarters, owing to the greater velocity which the projectile has at the first part of its trajectory.

† *Vide* a paper on the "Derivation of Elongated Projectiles," ("Proceedings, R.A. Institution," Vol. IV. p. 180); also Owen's "Modern Artillery," p. 257.

"that the derivation of cylindrical or flat-headed projectiles* is in the opposite direction to that of projectiles with conoidal or pointed heads, fired with similar rotation. For instance, if a cylindro-conoidal and a flat-headed shot be both fired with right-handed rotation, the derivation of the former will be to the right and the latter to the left."

There seems to be no doubt that flat-headed projectiles, for direct fire under service conditions with right-handed rotation, drift to the *left;* but for indirect and high-angle fire they may be driven to the right. It depends upon the direction of the rotation impressed on the projectile by the resultant of the resistance of the air.

Varying conditions which affect the drift.

All possible conditions may be stated thus (supposing right-handed rotation of the projectile) :—The resistance of the air, according to the shape of the head of the projectile, and the angle between its axis and the tangent to the trajectory, tends

Either to raise the head, (1), or to depress the head, ...(2)
according as C is before or behind G (Fig. 1).
If the 1st, the axis of the projectile commences to gyrate to the right; .....(3)
if the 2nd, the axis commences to gyrate to the left. .....(4)

In the case of (3), if the resultant of the resistance makes a greater angle with the axis of the projectile than the axis of the projectile makes with the tangent to the trajectory (as in Fig. 1), the projectile will drift for the first half-gyration to the right, in the second half-gyration to the left, but the drift on the whole will be to the *right,* for reasons before mentioned; but if the resultant makes a smaller angle, the projectile will drift for the first half-gyration to the *left,* in the second half-gyration to the right, but the drift on the whole will be to the *left.*

In the case of (4), if the resultant makes a greater angle with the axis of the projectile than the axis of the projectile makes with the tangent to the trajectory, the projectile will drift for the first half-gyration to the *left,* in the second half-gyration to the right, but the drift on the whole will be to the *left;* but if the resultant makes a smaller angle, the projectile will drift for the first half-gyration to the *right,* in the second half-gyration to the left, but the drift on the whole will be to the *right.*

It will be seen from the above how very complicated the question of the drift of elongated projectiles becomes, on account of the varying conditions of shape of head, steadiness of the projectile, &c.

Practical conclusions.

The practical conclusions with regard to drift are :—

(1) With service ogival-headed projectiles and right-handed rotation, the drift is to the *right.*

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* By "flat-headed projectiles" are meant cylindrical-shaped projectiles [▭]. If the shoulder is rounded off, the centre of resistance may be in front of the centre of gravity [▭), and the drift would be to the right.

(2) With left-handed rotation, under similar conditions, the drift is to the *left*.

(3) With flat-headed projectiles, the drift with right-handed rotation is generally to the *left*.

For the method of determining the drift for any particular piece, and the allowance made to compensate for it in the sighting, *vide* "Treatise on Construction and Manufacture of Ordnance," 1877, pp. 56, 57.

When very low charges are used in high-angle firing, it is found that the projectile strikes the ground base first; with a little more charge, the projectile falls on its side; and with a still higher charge, the projectile strikes the ground nearly point first.

(*To be continued.*)

THE BLOCKADE OF THE FORTIFIED POSITION OF PLEVNA, AND THE SURRENDER OF THE TURKISH ARMY, 28TH NOVEMBER, 1877.

(*Report of General Aide-de-Camp Todleben to his Imperial Highness the Commander-in-Chief of the Allied Armies.*)

TRANSLATED FROM THE RUSSIAN BY

LIEUT. J. M. GRIERSON, R.A.

ROUND about Plevna the army of Osman Pasha had occupied a fortified camp which was very well adapted for defence, presenting, as it did, successive lines of strong positions, which the enemy, in the course of our long sojourn before Plevna (since the end of July), had considerably strengthened, having profited by all the advantages of the terrain, and adapted his works very skilfully to it. The resistance which was opposed to us by the defenders of these fortifications was increased in a most remarkable degree by the fire—unprecedented in its strength—from rapidly-loaded rifles, and by the immense reserve of cartridges, permitting the enemy to cover with a hail of lead all the terrain in front of his works to a distance of two versts. Besides, the positions of the enemy, by their extent and depth, made it possible for him to keep reserves out of range of our artillery, and all the ravines and valleys converged on the town itself; so that the reserve could, on account of its central position, in case of an attack from our side, arrive at whatever point it liked of the attacked fronts. Those circumstances, in the highest degree unfavourable for us, explain the true causes of our failure in the storm attempted on the 30th August on the Plevna redoubts; and, to escape an aimless carnage, the solution of the problem was to desist from all new attempts to take possession of the position of Plevna by force, to await the arrival of reinforcements, and to reduce the Turkish stronghold by blockade.

From the arrival of the Guard Corps before Plevna, and the occupation by them of Gorni Dubnik on the Sofia road on the 12th October, may be dated the complete blockade of Plevna. The communications of Osman Pasha were then finally cut, and from that time there remained to his army one of two courses—to cut its way out through the lines of the investing army, or to lay down its arms when all the reserves of provisions were exhausted.

The duration of the resistance of the Turkish army in Plevna, and therefore of the investment, were closely connected with the question of food. To determine the precise quantity of provisions which the army of Osman Pasha had with it was difficult enough; but by calculations, and from our own knowledge, we were enabled to arrive at the conclusion that the supplies of the Turkish army in Plevna were not sufficient for more than two months.

Having made all arrangements for the capture of Plevna, and the taking prisoner of the Turkish army by a system of investment, there remained only to follow inflexibly an uniform plan of action: to sedulously abstain from all partial attempts at a storm—which could not lead to any decisive result, and only augmented our losses unnecessarily—and all the time to press forward the investment line as much as possible; taking, however, all necessary measures for the reception of the enemy should he attempt to cut his way through any part of our lines.

With this view there was ordered: the strengthening of all the positions of the investing army by lodgments, trenches, batteries, and in the more important points by lunettes and redoubts; the concentration of the artillery fire against the enemy's works; and the gradual approach of the trenches and lodgments to such a distance from the enemy's works as to draw off as much as possible of his rifle fire from our batteries. Next in importance came the construction of convenient roads throughout the position, and the erection of sign-posts on them for the movements of the troops in the investment line, the building of bridges, and the establishment of telegraphic communication round all the investment positions; in short, all measures were taken to meet the enemy, in case of an attempt to break through, if possible with the greater part of the army, by a timely concentration on the point chosen by him for the attack. This chain of fortified positions round Plevna, with a front of 70 versts, was divided into six sectors, for the defence of each of which a portion of the army was told off,* corresponding in strength to the relative importance of each. There were marked out for all the commanders of sectors the possible cases of a sortie, and the proportionate concentration of troops on the menaced point. Besides that, a few days before the actual advance of the army of Osman Pasha into the field, I conducted a manœuvre in the sectors entrusted to Generals Ganetski and Katalei, for the exact calculation of the time necessary for the concentration of the forces, in the supposition of a

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* See Notes 1 and 2.

decisive attack on the defences of our investing army. Under such circumstances the attack of the 28th November arrived.

From reports received by the Staff of the army from all the sectors of the investment in the course of the 27th November, as also from the testimony of deserters,we came to the conclusion that Osman Pasha was about to undertake a decisive sortie against the line of defence of the investing army. On the 26th, the fire of the hostile artillery had sensibly grown feebler, on the 27th it absolutely ceased. Deserters reported that the reserves of biscuit and shoes had been distributed to the troops, and their ammunition also replenished and examined. On the Sofia road, and round about the town, a great movement of troops was perceived, and a concentration in the more important Turkish camps of troops and baggage wagons. On the river Vid the Turks were working at the construction of a bridge under cover of the guns of the Oponetz redoubts. All these signs proved that the enemy were preparing for a sortie, and that the attack would in all probability be directed against the sector of General Ganetski.

In view of this, I made a preliminary report of all these circumstances to the Commander-in-Chief of the army, H.H. the Prince of Roumania, and with his permission I gave the following orders :—

1. One brigade of the 16th Infantry Division, with three batteries, and one brigade of the 3rd Foot Guard Division, under Lieut.-Gen. Skobeleff, to move at daybreak to the left bank of the Vid. The brigade of the 16th Division, and the three batteries, to take post near Dolni Dubnik, and be ready to reinforce the troops of General Ganetski; the brigade of Guards opposite the two nearest redoubts, but on the left bank of the river Vid, ready to support, according to circumstances and their actual requirements, the troops of Generals Ganetski or Katalei.

2. The other brigade of the 16th Division, with three batteries, to remain in its actual positions, in a constant state of readiness to turn out.

3. The three battalions of the 3rd Rifle Brigade, included in the troops of the 4th Sector, to move early in the morning of the 28th November to the village of Grivitza, to strengthen the troops of the 2nd Sector, under Lieut.-Gen. Krüdener.

4. The advanced position on the Plevna-Lovtcha road, from the Mikrovitsa redoubt to the Tutchenitsa ravine, to be occupied by a brigade of the 30th Division. The other brigade of the 30th Division to remain in the camp on the Rijine Hill, but ready to turn out. The command of the troops remaining in the 4th Sector to be given to Major-General Shitnikoff.

5. Four battalions of Roumanians and three batteries to move early on the 28th from Verbitsa to Grivitsa.

In Verbitsa there were already four battalions of Roumanians, with two batteries, ready to turn out. The sector of General Ganetski was thus strengthened, and the above distribution of troops enabled us also to reinforce the troops of the next sectors should a false attack be directed on them by the Turks, to draw off our attention from the main point of attack.

In the night from the 27th to the 28th November a deserter reported to the commander of the picquet on the Plevna-Lovtcha road that the Krishine redoubt had been evacuated by the Turks. General Skobeleff ordered a party of riflemen to advance, to ascertain the truth of this report; they found the redoubt deserted by the enemy, and later on in the morning of the 28th the Greater and Less Krishine redoubts, and also the trenches on the Green Hill, were in possession of the troops of the 30th Division.

Simultaneously with the news of the taking of the Krishine redoubts by our troops, about 9 a.m., the report reached me that the Turks had evacuated Redoubt No. 10, and that the Roumanians had captured the redoubt opposite Grivitsa.

In these circumstances, I ordered all the troops on the right bank of the river Vid to advance to the attack, and the brigade of the 16th Division, with three batteries, and soon also the 9th, 10th, and 11th Rifle Battalions, which had not yet begun their movement towards Grivitsa, to follow to the left bank of the Vid, and join themselves to the detachment of General Skobeleff.

At 12 noon the Emperor came to the Imperial redoubt between the village of Radichevo and the Tutchenitsa ravine, whence His Imperial Majesty was able to follow the advance of our troops from the eastern line of defence and the battle on the left bank of the Vid.

At daybreak began the battle between the army of Osman Pasha and the troops of General Ganetski. In the night from the 27th to the 28th November, the troops on guard in the parts of the position occupied by the Grenadiers were: in the 2nd Grenadier Division the 5th (Kiev) Grenadiers, in the 3rd the 9th (Siberian) Regiment. These troops occupied all the lodgments in the investing line. The immediate supports of these two regiments were furnished by the other two regiments of the brigades—viz., the 6th (Taurida) and the 10th (Little Russian) Grenadiers. All the 9-pr. guns of both artillery brigades were distributed in the batteries of position of the investing line, the 4-pr. batteries remaining with the second brigades of their divisions, and forming the reserve, which was stationed at Gorni Netropol and Dolni Dubnik. The lodgments to the north of Gorni Netropol and the village itself were occupied by the 17th (Archangel) Regiment of the 1st Brigade, 5th Division, with two Roumanian batteries; the 18th (Vologda) Regiment of the same brigade was kept in reserve with two batteries.

Already in the night cavalry patrols had reported the concentration of important Turkish forces on the river Vid, but the strength of the force brought against us was not discovered till we were attacked at 7.30 a.m. To support our chain of picquets, Major-General Daniloff, of His Majesty's suite, ordered the 2nd Battery, 3rd Grenadier Artillery Brigade, occupying the Battery of Position No. 3, to open fire, and the 10th (Little Russian) Grenadiers to move to Kopani Mogil, and at the same time called up the 2nd Brigade of the division with the 4-pr. batteries.

While these dispositions were in course of execution, it had become just sufficiently light to enable us to examine in detail the forces con-

centrated against us in the night, which were accompanied by a large number of carriages of every sort. The Turks, having opened fire from their guns in position on the heights near and below the bridge, along the course of the river Vid, rapidly deployed their troops and advanced to the attack, extended in the valley and covered by the gentle undulations of the ground on our side of the bridge, which permitted them to make their dispositions under cover for an attack with the great masses of men which had crossed to the left bank during the night.

This threatening movement of the enemy, directed against the lodgments of the 3rd Grenadier Division, was carried out with remarkable bravery. In front advanced a thick chain of skirmishers, who were closely followed by their supports in close order; these were succeeded by the reserves. Artillery accompanied the chain of skirmishers, which also moved quickly forwards, only halting to fire a round or two, and then following the skirmishers again.

Notwithstanding the hot fire of all our 9-pr. batteries and that of the infantry which had occupied the shelter-trenches, the Turks only took three-quarters of an hour to pass over the ground which separated them from our position and to reach the advanced posts of the investing line near Battery No. 3, which were occupied by the 3rd Grenadier Division. The enemy having penetrated the intervals between the works, and having disabled by his fire almost all the defenders of one, the weak remainder of the garrison, being unable to hold it, began to leave the work by the rear. When the trenches on the flank of Battery No. 3 were taken by the enemy, the work itself was attacked; and as the greater part of the gunners of the 2nd Battery were either shot or bayonetted, the artillerymen only succeeded in withdrawing two guns, but of the remaining six the breech-pieces were carried away.

In this way, at about 8.30 a.m., the troops which had occupied the centre of the position—viz., the 2nd Battalion and 2nd and 3rd Rifle Companies of the 9th Grenadiers—disordered by the great slaughter of the men and loss of officers, began to retire to Kopani Mogil and the left flank lunette. The 3rd Battery, 3rd Grenadier Artillery Brigade, occupying Battery No. 4, held it for some time, firing case; but, menaced by a turning movement on its right flank, it retired from the position, but only carried off six guns, as all the horses of the others were disabled.

The 10th (Little Russian) Grenadiers arrived at the right moment to support the Siberian Regiment, and, formed in company columns (*po-rotno*) in two lines, moved on the interval between Lunette No. 4 and Kopani Mogil. Rallying the Siberians, the Little Russian Regiment stopped the advance of the enemy with considerable loss; in a few minutes three battalion commanders and half the company chiefs were put *hors de combat*. The successful and determined attack of the enemy now assumed a threatening character for us; the 1st Brigade, 3rd Grenadier Division had become much enfeebled in holding the lunettes confided to it; eight of our guns were in the hands of the enemy, and the 2nd Brigade, 3rd Grenadier Division, had not yet come up to support the 1st.

About 10 a.m. the 2nd Brigade arrived to take part in the battle. At the same time the news was received that the 8th (Moscow) and 7th (Samogitian) Grenadiers of the 2nd Grenadier Division had come up to support the 3rd Division. The arrival of these reinforcements assured to us the successful termination of the struggle, and completely prevented the enemy from overcoming the resistance opposed to him. At 10.30 a.m. the thundering "Hurrahs!" which broke forth announced the attack of the 2nd Brigade, 3rd Grenadier Division, on our trenches which had been occupied by the enemy. Having driven the Turks from both lunettes, the Astrakhan and Fanagorian men, supported by the Siberians and Little Russians, advanced quickly to the attack, and, disregarding their losses caused by the *feu d'enfer* of the enemy, they drove the Turks out of the trenches with the bayonet. Our guns which had remained in the hands of the enemy were retaken, and the Astrakhan regiment also took seven Turkish guns and a colour.

Two battalions of the 18th (Vologda) regiment, which had moved early to the left flank lunette and were near the trenches of the position of the grenadiers, executed a flank attack on the enemy, in which they were supported by the fire of the Roumanian batteries.

Simultaneously with the attack of the 2nd Brigade, 3rd Grenadier Division, the 7th (Samogitian) Grenadier Regiment arrived on the battle-field at 10.45 a.m., led by the commander of the 2nd Grenadier Division, Major-General Svetchinim, in the interval between Gorni and Dolni Netropol. The 3rd Battalion of this regiment found a part of the lodgments of the 3rd Grenadier Division occupied by the enemy. Advancing with the bayonet, the Samogitians drove the Turks out of the lodgments without firing a shot, and having forced the intact bodies of Turkish troops to retreat, they took three guns.

Having occupied once more the advanced lodgments, our troops paused for a moment. It was about noon when the Turks began to retire slowly to the river Vid, covered, however, by a powerful fire. The guns taken from the enemy, which had not yet been rendered useless by him, were turned against the Turks by our infantry. At the same time, all the batteries of the 3rd Grenadier Artillery Brigade were pushed forwards, and, having taken up a position in alignment with the infantry, they opened on the retiring Turks with shrapnel. The retreat of the enemy gradually assumed the character of a rout. Thick disordered crowds of Turks poured towards the bridge, and got mixed up with the train wagons, covering with their heavy masses the ground about the high road. In the face of the complete defeat of the Turkish army, and the terrible loss inflicted upon it, Osman Pasha could no longer think of prolonged resistance, all the more as the troops of the other sectors of the investing line had advanced to the attack. Besides, the expected arrival of the 16th Division and the participation in the defence by the brigade of the 3rd Guard Division, which was coming up, completely assured to us the final defeat of the enemy.

Soon the troops along the whole line advanced to the attack. The division of General Daniloff moved forwards, supported on its left flank by the defenders of Gorni Netropol, the 1st Brigade, 5th Division, and on the right by the 2nd Brigade, 2nd Grenadier Division. The 1st

Brigade, 2nd Grenadier Division, advanced from its trenches and tried to envelop the Turkish left flank. The 2nd Battalion, 5th (Kiev) Grenadiers, and one battalion of the 6th (Taurida) Regiment, were directed also towards the ford on the river Vid, to occupy the heights on the right bank of the river. The Grenadiers, having crossed the river up to their waists in water, climbed the heights of Blazevatz and captured the hostile redoubt, the garrison of which surrendered without firing a shot.

The brigades of the 16th and 3rd Guard Divisions, which were brought up, conformably to the orders given by me on the 27th Nov., to strengthen the troops of General Ganetski, took no part in the battle. According to a report of Lieut.-General Katalei, he sent across to the left bank of the Vid at 7 a.m. on the 28th November six battalions of the 3rd Guard Division, with two batteries, under Major-General Kurloff. At 10 a.m. this force, at the request of General Ganetski, took post at Dolni Dubnik, where it received an order from the commander of the Corps of Grenadiers to advance by the Sofia road and attack the left flank of the enemy. As this movement was commencing, General Skobeleff arrived, and having assumed command of those troops, ordered General Kurloff to halt his command, to keep them as a reserve, and to await the arrival of a brigade of the 16th Division. Having remained about two hours, and not having received further orders from General Skobeleff, General Kurloff again moved his troops forward on the Sofia road, till he reached the bridge over the Vid, when the battle was already over.

At the time when the 2nd and 3rd Grenadier Divisions were heroically repulsing the attacks made against them by the entire Turkish army, the troops of the nearest sectors of the investing line, under the command of Lieuts.-General Zotoff, Baron Krüdener, and Katalei, Major-General Shitnikoff, and the Commander-in-Chief of the Roumanian Army, General Tchernat, had advanced against the hostile works on the east and south fronts. The greater part of these works were already evacuated by the Turks, and the troops, in presence of His Imperial Majesty, entered the town of Plevna. Having occupied the town, the troops, under the personal orders of your Highness, continued the attack, with your Highness at their head, to the river Vid, in rear of the enemy, and by degrees were concentrated on the ridge of the hills to the south of Plevna, near the Sofia road.

The Roumanian troops, with whom His Highness Prince Charles remained during the whole time of the advance to the river Vid, met with resistance from the defenders of the Oponetz redoubts, still occupied by the enemy. After a protracted struggle, the defenders of these works laid down their arms, and the Roumanians took three guns and 2000 prisoners.

General Katalei having remarked the retreat of the Turks to the river, resolved to attack the redoubts opposite the Volhynian Hill with the battalions of the 3rd Guard Division, which had remained on the right bank of the Vid, with a view to preventing the return of the enemy into the fortified camp. At 11·30 a.m. the Rijine redoubt was taken without a struggle, and after an insignificant resistance the

Mahomet Tabia surrendered also. About noon, after a short action, the "Sugar Loaf" and the "Black Redoubt" were occupied, and, soon after, the redoubt behind them. In these works there were taken by the Guards one pasha, 120 staff and superior officers, and 3,634 men of lower rank, and four guns. The losses on our side were confined to 3 killed and 15 wounded of the lower ranks.

The Turks, pressed on all sides by the superior attacking forces, could no longer sustain the fight. They sent out parlementaries; and riding for this purpose to General Ganetski, the Chief of the Turkish Staff declared that Osman Pasha was wounded, and wished to know the terms of capitulation. General Ganetski requested an unconditional surrender of the whole army, and to receive the consent of Osman Pasha he personally advanced to meet his brave and resolute wounded enemy.

On the memorable day of the 28th November there surrendered as prisoners 10 pashas, 128 staff officers, 2000 superior officers, and 40,000 of inferior rank of the infantry and artillery, and 1200 of the cavalry. 72 guns were taken, and a large amount of warlike stores—in particular, of small-arm cartridges. The losses suffered by the enemy in the last battle were reckoned at 6000 men.

On our side the losses were as follows:—

	Generals.	Staff Officers.	Superior Officers.	Lower ranks.	
2nd Grenadier Division } 3rd. " " }	0	2	7	409	killed.
2nd and 3rd do.	1	3	47	1263 }	wounded.
1st Brigade, 5th Division	0	0	1	47 }	

Thus was overcome the resistance of the fortified camp of Plevna. By completely investing the town, by not running the least risk, and by constantly prohibiting a storm of the Turkish works, the required end was fully attained. The result was the surrender of 40,000 men of the best hostile army, and the occupation of a most important strategic point which closed the principal road of Western Bulgaria. During this time, our own troops were not only rested and reorganised, but the battalions were raised to their full strength, and made ready, in strength and spirits, for renewed exertions for the glory of the Russian arms.

In conclusion, I wish to bring to the favourable notice of your Imperial Highness the services of the following officers:—The Chief of the Staff of the Army, Lieut.-General Prince Imeretinski, who was my invaluable second in this troublesome operation which was crowned by the success of the 28th November; those who were Chiefs of Sectors of the investing line—viz., Lieut.-General Ganetski (to whom, with the Grenadier Corps, is due the honour of the last day of the blockade of Plevna); Lieuts.-General Zotoff, Baron Krüdener, Katalei, and Skobeleff; the Commander of the Roumanian Corps, General Tchernat; the Director of the Artillery of the Attack, Major-General Moller; and Major-General Reutlinger, who filled the functions of Commanding Engineer of the Army.

Having been for two months a witness of all the deeds of the army before Plevna—of its steadiness, its bravery, its self-denial in constant

trials and hardships of every kind—I, with an expression of profound regard for the troops, bear witness before your Imperial Highness that the conduct of all ranks of the army investing Plevna, from the General to the soldier, was worthy of the highest praise.

(Signed)

TODLEBEN.

Note I.

Distribution of the Forces investing Plevna.

Sector.	Extent.	Troops.	Bn.	Sqd.	Batt.
I.—General Tchernat	Bivolar to Grivitsa (20 kils.)	3rd Roumanian Divn. } 4th " " }	19	4	7
II.—Baron Krüdener	Grivitsa Redoubt to Galitz Redoubt (10 kils.)	31st Infantry Divn.	12	0	0
		31st Artillery Bde.....	0	0	6
		2nd Bde., 5th Divn.	6	0	0
		5th Artillery Bde.	0	0	4
		Total 2nd Sector.....	18	0	10
III.—General Zotoff.....	Galitz Redoubt to Tutchenitsa Ravine (8 kils.)	2nd Infantry Divn.	12	0	0
		12th Rifle Battalion	1	0	0
		30th Artillery Bde.	0	0	6
		Total 3rd Sector.....	13	0	6
IV.—General Skobeleff	Tutchenitza to Kartujavena Ravines (9 kils.)	16th Infantry Divn.	12	0	0
		30th " "	12	0	0
		9th, 10th, & 11th Rifle Bn.	3	0	0
		2nd Artillery Bde.	0	0	6
		16th " "	0	0	6
		9th Don Cossacks.....	0	6	0
		Total 4th Sector	27	6	12
V.—General Katalei	Kartujavena Ravine to right bank of Vid, at the village of Truina (10 kils.)	3rd Guard Division	16	0	0
		Emperor's Guard Cossacks	0	2	0
		10th Don Cossack Batt....	0	0	1
		3rd Guard Artillery Bde.	0	0	6
		Total 5th Sector	16	2	7
VI.—General Ganetski	Left bank of Vid, at Truina, to left bank at Bivolar (20 kils.)	2nd Grenadier Divn.	12	0	0
		3rd " "	12	0	0
		5th Divn. 1st Bde.	6	0	0
		2nd Roumanian Divn. ...	8	0	3
		2nd Grenadier Art. Bde.	0	0	6
		3rd " "	0	0	6
		5th Artillery Bde.	0	0	2
		9th (Kazan) Dragoons ...	0	4	0
		9th (Bug) Uhlans	0	4	0
		9th (Kiev) Hussars	0	4	0
		4th Don Cossacks	0	6	0
		7th Horse Artillery Batt.	0	0	1
		2nd Don Cossack Batt....	0	0	1
		— Regiment Calarassi ...	0	4	0
		Total 6th Sector	38	22	19
Grand total	131 battalions. 34 squadrons. 61 batteries (13 at 6 guns, 48 at 8 guns; total, 462 field guns.)				

Note II.

Order of Battle of the Russian Troops investing Plevna.

Grenadier Corps.—Lieut.-General Ganetski:—

2nd Division. (Schwitchinim.)	1st Brigade	(von Manteuffel), 5th (Kiev), 6th (Taurida).
	2nd "	(Gadon), 7th (Samogitian), 8th (Moscow).
3rd Division. (Daniloff.)	1st "	(Sorokin), 9th (Siberian), 10th (Little Russian).
	2nd "	(Kevitnitski), 11th (Fanagorian), 12th (Astrakhan).

2nd and 3rd Grenadier Artillery Brigades.

Fourth Corps.—General Zotoff:—

16th Division. (Skobeleff.)	1st Brigade	(Tebiakin), 61st (Vladimir), 62nd (Susdal).
	2nd "	(Grenkwitz), 63rd (Uglitz), 64th (Kazan).
30th Division. (Shitnikoff.)	1st "	(Poltoratski), 117th (Jaroslav), 118th (Schouia).
	2nd "	(Bosherianoff), 119th (Kolonim), 120th (Serpuchoff).

16th and 30th Artillery Brigades.
4th Cavalry Division—4th Don Cossacks.

Ninth Corps.—Baron Krüdener:—

5th Division. (Schildner-Schuldner.)	1st Brigade	(Rodionoff), 17th (Archangel), 18th (Vologda).
	2nd "	(Bogazevitch), 19th (Kostroma), 20th (Galitz).
3rd Division. (Welianimoff.)	1st "	(Bielokopitoff), 121st (Pensa), 122nd (Tambov).
	2nd "	(Brandt), 123rd (Kozloff), 124th (Voronej).

5th and 31st Artillery Brigades.

9th Cavalry Division. (Lashkareff.)	1st Brigade	(Ratiejev), 9th Dragoons (Kazan), 9th Uhlans (Bug).
	2nd "	(Olderop), 9th Hussars (Kiev), 9th Don Cossacks.

16th Horse and 2nd Don Horse Battery.

3rd Foot Guard Divn. (Gen. Katalei.)	1st Brigade	(Philosophoff), Lithuanian and Keksholm.
	2nd "	(von Brunsen), St. Petersburg and Volhynian.

3rd Guard Artillery Brigade and 10th Don Battery.
Emperor's Guard Cossacks (2 sotnias).

2nd Division.	1st Brigade	(Rasgildejeff), 5th (Kaluga), 6th (Libau).
	2nd "	(Kvitnitzki), 7th (Revel), 8th (Esthonia).

2nd Artillery Brigade.

3rd Rifle Brigade. (Dobrovolski.)	9th, 10th, 11th, and 12th Battalions.
2nd Sapper Brigade.	2nd, 3rd, and 4th Sapper Battalions.
	2nd Railway Battalion.
	1st Siege Engineer Park.
	3rd and 4th Telegraph Park.

RUSSIAN ARTILLERY TACTICS DURING THE LATE CAMPAIGN.

BY

LIEUT. A. M. MURRAY, R.A.

Adverse criticism of artillery due to its failure during the Russo-Turkish campaign.

THE insignificant part played by the Russian artillery in all the earlier battles of the late war has caused many people to lose all faith in the arm as an effective weapon of modern warfare. Forgetting the astounding successes achieved by the German artillery in the campaign of 1870–1, and looking only at the failure of the Russian artillery in the combats round Plevna and in Asia, most of the writers about the late war, without investigating the causes of that failure, have raised an outcry against modern artillery in general, and sought to discredit its value on the field of battle. We are told, for instance, that "the effect of modern artillery and its value have been greatly over-estimated;" that the material effect of shell fire is "very slight," while "upon good troops its moral effect is nearly lost;" that "in the wars of Napoleon artillery was a far more effective arm on the field of battle than modern artillery, with all its improvements;" and much more to the same purpose.* Nor do the critics who write thus forget to remind us that the distinguished author of the "Operations of War"—an artillery officer of high rank, whose name will never be mentioned in this Institution but with respect—writing after the Franco-German war, laid it down as a new principle of tactics that the comparative effect of the smooth-bore on the field of battle was greater than that of the rifled

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* "Daily News" correspondence of the war between Russia and Turkey. The chapter which contains this sweeping condemnation of artillery is, I believe, from the pen of the late Mr. MacGahan. I have quoted the above passages as an example of the sort of criticism to which artillery has been subjected since the war. Mr. MacGahan is unfortunately not our only critic. Even so generally well-informed a paper as the "Army and Navy Gazette" joins in this dead set made at artillery. Thus we are told that "artillerymen are striving hard to prove that their arm is far more formidable than the experience of the Russo-Turkish war would lead those who study the subject to suppose. . . . . We maintain, however, that it is by no means so indispensable an adjunct to infantry as infantry officers have hitherto thought, and as artillery officers still assert it is."—*Army and Navy Gazette, 7th September, 1878.*

gun now, and that infantry fire has surpassed that of artillery in the degree to which its power has been augmented.*

The real cause of the failure of the Russian artillery is due to the bad tactics of the Russian artillerymen.

If the purpose of this paper were to argue the general question which has been raised as to the relative improvement in artillery and infantry fire, it would be easy to point to authorities—and high authorities, too, both in Germany and in England†—who are not by any means content to accept this new principle of tactics laid down in the "Operations of War." Passing from this question, however, my object now is to endeavour to show, from a short analysis of some of the chief battles of the late campaign, that the cause of the failure of the Russian artillery is to be looked for, not in the general decadence of the arm as a whole, but in the faulty tactics of the Russian commanders and the Russian artillerymen, in their inability to appreciate the necessity of combined action with the infantry, in their want of confidence in their arm, and above all in their having neglected to learn all those lessons which the war of 1870–1 taught about the employment of artillery in the field. The Russian artillery in all the early battles of the war never, or rarely ever, had a fair chance of asserting its proper position on the field of battle. It was handicapped throughout by the incompetence of its feeble leaders. What an eminent German critic‡ said of the conduct of the French artillerymen in the war of 1870–1 is strictly true of that of the Russian artillerymen in the war of 1877–8 :—"The right tactical idea was wanting all through, as well as practice in deployment and in the execution of the necessary manœuvres."

Comparison between the tactics of the German artillery in 1870–1 and the Russian artillery in 1877–8.

When, therefore, it is asked how it was that the Russian artillery, which in respect of armament was acknowledged to be superior to the artillery of the German army in 1870, broke down so completely when it was tried last year, the answer is, I think, clear. The German artillery won its successes because it was used according to certain definite laws or principles of tactics which after the campaign of 1866 were formulated into a system, and which the German artillerymen

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* As enormous progress has undoubtedly been made in the science of artillery since the Franco-German war, it is quite possible that General Hamley may have modified his views upon the subject since writing the chapter in the "Operations of War" to which I have alluded. A recent writer in the "Times" newspaper (August 30th, 1878), in an excellent paper on the "Further Progress of Artillery," brings statistics to show that, from experiments made at Okehampton and more recently at Madrid, the effect of shrapnel shell fired from rifled guns is five times as great as that of common shell. In the war of 1870-1 the German artillery had no shrapnel. If, therefore, the writer in the "Times" be correct—and he supports his argument with a strong array of facts—we may believe that the field artillery of the future, if properly used, will produce results five times as great as those "grand and decisive" results of the German field artillery at the battle of Sedan.

† Notably Lt.-Colonel C. B. Brackenbury, R.A., who, in an article written for the "Nineteenth Century," of July, 1878, entitled "Iron-clad Field Artillery," thus alludes to General Hamley's assertion that the relative power of artillery as compared with that of infantry has on the whole diminished :—"I should not hesitate," he writes, "to break a lance with him on this question, but that for present purposes it is more convenient to accept his decision, and to admit that weapons which have had their range, their mobility, their intelligence (if the expression may be allowed), and their destructive power enormously increased, still lack something to enable them to retain their old place in the hierarchy of arms, though the weapons which are supposed to have risen a step have only advanced in range and rapidity of firing."—*Nineteenth Century, July, 1878.*

‡ Boguslawski. "Tactical Deductions from the War of 1870–1."

were trained to follow in time of peace, and so were able to carry into practice in war; and when we find the Russian artillerymen systematically disregarding these laws or principles of tactics, we ought not to be surprised if we find that they failed to secure the same results which the German artillerymen did when they acted in obedience to these laws or principles.

What are these principles of offensive artillery tactics? They may be broadly stated as follows:—*

Five elementary laws or principles of modern artillery tactics.

1st Law.—A powerful artillery fire must be developed as early as possible in the action.†

The object of this preparatory artillery fire, which should be as preponderating as possible, is twofold—to silence the enemy's artillery fire, and to demoralise the enemy's infantry, and so prepare the way for the attack. To secure this object, (*a*) the greater proportion of the artillery must be kept well to the front in the columns of route;‡ (*b*) guns must be massed when deployed, to secure unity of command and concentration of fire.§

2nd Law.—It is the duty of the artillery not only to prepare the way for the infantry, but to assist the infantry in its attack.‖

3rd Law.—There must be no waste of ammunition at long ranges; guns must be moved as soon as possible to decisive range.

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* These principles, deduced from the experience of the war of 1870–1 and from the writings of all the recognised authorities on tactics, must form the basis of any system of artillery tactics for modern field artillery. The authorities from which they are derived are the following:—

"Proceedings, R.A. Institution," No. 5, Vol. VIII.
"Notes on Artillery in the Field," by Lt.-Col. W. J. Williams, C.B., published in "Proceedings, R.A. Institution," No. 2, Vol. IX.
"R.A. Institution Prize Essay for 1876," by Col. H. A. Smyth, R.A.
"German Official Account of the War of 1870–1."
Hoffbauer, May, Boguslawski, and other writers.

† "A preparatory fire," says Capt. May, "of small-arms against the defenders who are under cover will never have the effect of rendering a storm possible. According to the most simple calculation, the storming party, however strong its columns, will be repulsed, always supposing the position to be held by brave troops. But nothing can withstand a powerful preparatory attack by artillery; if the element to be broken be the infantry, it can only be done by this means."—*Tactical Retrospect.*

‡ "At all parts of the extensive battle-field the whole strength of the batteries was from the first brought into play. Inserting themselves in the columns of route in a position favourable to early deployment, they hastened forward to the battle-field with the advanced parties of the infantry."—*German Official Account of the War of 1870–1.*

§ "It is, I believe, to the massing of guns, and their consequent unity of action, that the Prussians owed their great artillery success in the campaign of 1870."—*Extract from a lecture delivered before H.R.H. the Duke of Connaught, at the U.S. Institution, by Lt.-Col. H. Brackenbury, R.A.*

‖ On this point Colonel H. A. Smyth, R.A., says:—"By the time that the skirmishing front of the infantry attack comes under the aimed musketry fire of the defence, as much of the artillery of the attack as the ground will allow must be already in its last and decisive positions, bearing directly on the actual point determined for the delivery of the assault, and on the collateral lines; enfilading where it is possible, regardless of losses, straining every nerve (at such short range that none of its efforts will be wasted) to overwhelm with its fire, to disorganise and quell the defenders—daring everything in the intention of bearing the infantry through the last arduous crisis, and of thus securing the success of the whole."—*R.A. Institution Prize Essay, 1876.*

It should always be remembered that the moral and material effect of artillery fire increases as the range diminishes.* Great losses of men and horses will be unavoidable if great results are looked for.

4th Law.—Guns are no longer to be regarded as colours; they must be fought to the last, even at the risk of being lost.†

5th Law.—Guns have nothing to fear from a front attack of infantry, provided their flanks are secured.‡

These laws were invariably disregarded by the Russian commanders in the first part of the war.

A careful study of the battles of the late war will show that, with the exception, perhaps, of the attack on Nikopolis on the 15th of July, 1877, the above-mentioned laws of artillery tactics during the greater part of the campaigns, both in Europe and in Asia, were invariably disregarded by the Russian commanders, who worked on an old and obsolete system; and it was not till towards the close of the campaign that they recognised their errors and modified their tactics accordingly. And as they suffered grievous losses at first by the feeble use they made of their artillery, so they won great successes in the end when they learnt how the full tactical power of the arm can be developed by right employment. The victory of the Aladja-Dagh goes far to rival that of

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* This is a most important point, and cannot be too strongly insisted on. As has recently been pointed out by Col. C. B. Brackenbury, an experiment made at Okehampton shows that the actual destructive effect of artillery fire increased steadily from 18 per cent. per minute killed at 1000 yds. to 75 per cent. at 100 yds., and this though the number of gunners was diminished to represent losses from the fire of the infantry. Again, Major S. J. Nicholson, R.H.A., who has given great attention to this question, writes very strongly to the same effect, and as the Russian artillery will meet with severe criticism later on for opening fire and remaining in action at long ranges, it is well to have the opinion of so high an authority distinctly recorded. He writes as follows:—"The great loss of power, and consequently of effect, which shrapnel suffer from increase of range, is so great that the responsibility of the officer who uses them at distant objects must be considerable. In any of the cases above stated, opening fire early may be absolutely necessary; the only responsibility remaining will then be that it is not continued one moment too long. If, however, there is no such absolute necessity, surely some very sufficient reasons should be demanded from an officer who, in the earlier and comparatively unimportant period of an engagement, when the effect produced could, from the length of the range, at best be but small, should expend ammunition which later on would be capable of exerting the enormous power that shrapnel at ordinary and short ranges has been shown to possess, and which might, if reserved for really critical periods, exercise a deciding influence on the fortunes of the day."—*Proceedings, R.A. Institution, No. 2, Vol. X.*

† "A battery which has maintained a destructive fire at a decisive point for five minutes—one minute even—and then is lost, has done more for the general good than 10 batteries which from well chosen positions in the rear have kept up a well-aimed, but, after all, a nearly ineffective fire."—*Der Kampf um Plevna*, by Capt. Von Trotha.

Though the losses in men and horses during the Franco-German war were enormous, the loss of guns was insignificantly small. At Gravelotte two guns were lost, and two were rendered unserviceable. At Sedan one gun burst. At Wörth, Borny, and Mars-la-Tour, although the German commanders used their artillery boldly, if not recklessly, they did not lose a single gun.

‡ This is an old maxim of Napoleon's. The experience of the Franco-German war does not lead us to believe that it is modified by the introduction of breech-loading small-arms. Hoffbauer quotes many instances of German batteries compelling French skirmishers to retire before their fire alone. Colonel C. B. Brackenbury, R.A., also lays down the principle that "whether acting offensively or defensively, artillery can protect its own front in ordinary open country, and should not retire before infantry unless the whole force is retreating."—*Journal of the U.S. Institution, No. 86, Vol. XX.*

Sedan as an instance of the "grand and decisive" results that can be obtained by a commander who knows how to use his artillery boldly and fearlessly in action.

It is time now to pass from allegation to fact. The battle of Zewin, in Asia, fought on the 25th of June, 1877, may be taken as a type of all the early battles of the war, and will serve as well as any other to illustrate the faulty tactics of the Russian artillery.

The battle of Zewin, fought on the 25th of June, 1877.

General Loris-Melikoff, advancing from Kars with 16 battalions of infantry, 52 guns, and some cavalry, found Mukhtar Pasha strongly entrenched in a position on his right flank above the village of Zewin. The Turkish force was 24 battalions of infantry and 2 batteries of artillery. Independently of the entrenchments, the position was one of great natural strength, and, although the Turkish commander had only 12 guns at his disposal, he had skilfully placed them so that they could sweep all the approaches with a powerful cross-fire. The main Turkish position was on a terrace in front of a high mountain, and owing to the configuration of the ground it could not be turned, but would have to be captured by a front attack. How did the Russian General proceed to attack? If ever there was a position which demanded a thorough artillery preparation before it was assailed by infantry it was that of Zewin. Did he, therefore, knowing how weak the Turks were in artillery, mass his guns in one large battery, and endeavour to crush the enemy's artillery with an overwhelming and concentrated fire? Did he then advance his batteries—the Turkish artillery being silenced—and at close and decisive range pour in a demoralising fire upon the Turkish infantry, and so render the position untenable before his own troops attempted to storm it? He did nothing of the kind. He began by dispersing his guns all over the field of battle. Dividing his attacking force into three main columns, he sent three batteries with the right column, one battery with the centre, and another battery with the left; while his two Cossack horse artillery batteries, which might have proved of the utmost value to him during the action, were sent with the cavalry to execute a long flank march to the southward, which some said would be four miles, others seven, but which eventually turned out to be 20 miles in length. These two batteries, in fact, took no part in the action whatever. What was the consequence of these dispositions? The batteries had instructions to act independently. There was no attempt at unity of command or concentration of fire. At long and impossible ranges, varying between two and three miles, they came into action, "one after the other," firing when and where they could. The Russian gunners, we are told, found some difficulty in hitting off the range of the Turkish batteries; which is not surprising when we learn the distance at which they opened fire. 4000 yds. is considered to be the extreme effective range of shrapnel shell fired from field guns against troops in the open, the atmosphere being clear, and the other conditions of firing favourable.* Here we have the Russian guns not only opening fire but

* "Report on the Artillery Experiments at Okehampton," p. 14. Major Nicholson, R.H.A., in his paper on "Shrapnel Fire," lays down 3500 yds. as a maximum range.

remaining in action for several hours at ranges varying between 4000 and 5000 yds., against troops which were strongly entrenched. So little effect had this desultory fire on the Turkish batteries, that for a long time they did not even reply. Their obstinate silence, indeed, led the Russians at one time to imagine that the Turks had abandoned the position. The Turkish gunners were in reality reserving their fire until the Russians came within effective range of their guns. Meanwhile, although the Turkish artillery was in no respect overpowered, the Russian infantry were ordered to attack; and against a position which was—as we are told—literally "seamed" with entrenchments did Heimann* hurl his battalions. The troops were met with a cross-fire of both artillery and infantry, the effect of which is thus described by an eye-witness who was on the Russian side during the battle:—"Our men," he writes, "descended to the ravine below, and then passed to the assault of the great hill with the main Turkish battery. There they again fell under a frightful cross-fire which the pen fails to describe. Single shots were rarely heard; the bullets flew thick, as if whole regiments were pouring in volleys upon us. The Turks, as we afterwards learnt, had brought up mitrailleuses. The result of this murderous fire could not be seen until the 14th showed themselves above the level of the first hill. . . . . This attack was speedily beaten off; it was 'Thus far and no farther!' Three separate attempts did they make to get forward, but all in vain, and the losses were immense. To fill the cup of misfortune, during the third attack one of the shells from our batteries fell among the first line of stormers, and killed several of our men." And this is the only allusion made by this eye-witness to the artillery throughout the action. It does not, indeed, appear that a single battery was advanced to support the infantry attack. In place of boldly pushing on, as the Prussian batteries did at Gravelotte and Sedan, side by side with the infantry, and pouring in a hot fire of shrapnel—the effect of which is practically annihilating at short and decisive ranges—the Russian guns seem to have remained stationary during the whole of the battle, doing little or nothing to divert either the enemy's artillery or infantry fire, which was concentrated with "terrible effect" on the Russian columns.

General Krüdener's attack on Nikopolis, 15th of July, 1877.

On only one occasion during the early part of the campaign was the Russian artillery well handled—viz., during the attack on Nikopolis. Finding the Turks, as usual, strongly entrenched in a position which is described as being well selected and made the most of, General Krüdener, the commander of the 9th Corps, brought up no less than 48 guns, the superior fire of which silenced the Turkish batteries in a few hours. Not till this was effectually done did Krüdener order the infantry to advance, which they then did—the Russian guns advancing with them, and taking up fresh positions close to the enemy. We find the artillery rendering most important aid to the infantry all through this action. Thus, "General Schildner-Schoulder received orders to carry the Osma bridge, which, however, he was not successful in doing

* This General appears to have been in executive command during the day.

until reinforced by a battery of Cossack horse artillery. The latter opened fire from a position which took the Turks in flank, and compelled them to fall back. . . . . When General Krüdener saw this he ordered a general advance of the infantry, and the six batteries east of Vubla moved forward to a fresh position nearer to the Turkish line." The Russians eventually obtained complete possession of the heights commanding the town and fortress of Nikopolis, which had no option but to surrender. Here we have an instance of sound artillery tactics on the Russian side. The position is first thoroughly prepared by the artillery; the enemy's artillery fire is subdued; there is then combined action between the artillery and infantry, whose united efforts compel the Turks to retire.

The battle of Nikopolis stands alone; everywhere else we find a repetition of the tactics of Zewin. We find infantry attacking positions without waiting for the artillery preparation;* we find guns dispersed instead of concentrated; we find them firing for hours, even for days together, at distant ranges;† we find them remaining stationary while the infantry are attacking; we find them withdrawn for fear of loss just at the very time when their fire would be most useful;‡ we find, in short, throughout the early part of the war, all the first principles of modern artillery tactics openly, repeatedly, systematically disregarded.

The battle of Nikopolis is a solitary instance of sound artillery tactics on the Russian side during the first part of the war.

It was not till quite towards the end of the war that the Russian commanders, taught by bitter experience, learnt how to make a right use of artillery in action. At the battle of the Aladja-Dagh, General Heimann (the same who commanded at Zewin) did not venture to attack the Aulia-Tepeh—the centre and key of the Turkish position—until he had massed no fewer than 67 guns, which, advancing to within 1800 yds. range, poured in for the space of three hours a storm of

Battle of the Aladja-Dagh, 15th of October, 1877.

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* Thus Mr. Archibald Forbes, in criticising Prince Schahofskoy's conduct during the second attack on Plevna, ascribes his frightful loss in men to this reason:—"A long and anxious inspection," he writes, "seemed to satisfy Schahofskoy and the chief of his staff that the time had come when the infantry could strike with effect. . . . . In other words, we were about to launch ten or twelve thousand men against commanding entrenched positions held by an immensely superior force, and no whit crushed by our preliminary artillery fire."

† All who witnessed the artillery attack on Plevna, which preceded the infantry assault in September, 1877, allude to the incredible conduct of the Russian artillerymen in continuing to fire, day after day, at long ranges which rendered their fire harmless. "Although yesterday evening the necessity of advancing the batteries nearer the Turkish positions was admitted on all hands, we found this morning, on looking at the position, that nothing of the kind had been done. The fire of the Turkish redoubt of Grivica does not seem to have slackened in the least."—*Daily News correspondence.*

Again, another eye-witness of the attack on the extreme left, near the Loftcha road, says:—"Imeretinsky's artillery is where it was yesterday, fully 2½ miles from the redoubts which he was attacking, and which cannot be even visible to his artillerymen."—*Daily News correspondence.*

The same complaint is made from Asia. An eye-witness of the battle of the Yahni-Tepeh, fought on the 2nd of October, 1878, laconically remarks that "on seeing from the Kaback-Tepeh some forty guns firing with a range of three miles at earthworks which were prudently left empty by the Turks, it seemed to me that the attack lacked the character which was likely to secure victory."—*Daily News correspondence.*

‡ "The Russians seem to be very much afraid of losing their artillery. I have already spoken of the unaccountable conduct of their artillery in stopping fire upon the Turkish redoubts when the attack began, and when it ought to have been hottest."—*Daily News correspondence.*

shrapnel fire such as threatened the utter annihilation of the defenders. The hill, rendered untenable by the artillery fire alone, was easily stormed by the Russian Grenadiers. A correspondent of the "Daily News" who was with the Russians during the attack, and visited the position shortly after it was captured, has given so graphic a description of what he saw, that it is worth recording here as an instance of what field artillery can effect when properly used. He, at any rate, does not seem to have considered the material effect of rifled guns to be "very slight," for he writes as follows:—"Rows of dead Turks, some horribly disfigured by shell fragments, were to be seen upon the earthworks and at the bottom of the ditches. Some were literally torn to pieces by the shrapnels. I think most of them were killed by the artillery, which indeed had done its duty this time. The inside of the redoubt was ploughed with shells and strewn with their fragments and bullets flattened on the stones. I don't think," he goes on to say, "that the Russians have sustained great losses by that assault; because the shrapnels told terribly on the Turks, and had greatly diminished their number and demoralised them before the storming began." To this testimony of an impartial eye-witness must be added that of Mukhtar Pasha himself, who, in a conversation after the battle, attributed his defeat, as Napoleon III. attributed his at Sedan, to the superiority of the artillery which was brought against him. Aladja-Dagh was, in fact, the Sedan of the campaign. The capture of the Aulia-Tepeh broke the Turkish centre, and the Russians gained a victory which, due as it principally was to the brilliant action of the artillery, is not unworthy of being placed side by side with some of the artillery feats of Napoleon I.

Lessons of the war.

There is, I venture to think, from the late war both a conclusion to be drawn and a lesson to be learnt.

The conclusion which a careful study of the war will surely lead us to draw is not, as has been asserted, that the *rôle* of artillery is played out, but, on the contrary, that the arm is more than ever necessary on the field of battle. The General who orders infantry to attack an entrenched position which has not been previously submitted to a searching artillery preparation is sending his men to certain slaughter. If any troops in the world could do what the experience of the last war shows to be impossible, the Russian infantry, led by such a man as Skobeleff, would surely have succeeded. Such attempts, however, can only end in crushing disasters, and if Zewin and Plevna will not satisfy the critics who assert that infantry are independent of artillery, let them go to that green hill side in Lorraine which is still marked by the graves of those 6000 Prussian guardsmen who fell in the short space of ten minutes at St. Privat—a ghastly testimony to the truth of the statement which is here made, viz., that infantry are helpless in battle without the aid of artillery.

Is not the lesson which artillerymen can learn from the war the same which was, as long ago as 1866, pointed out by the author of the "Tactical Retrospect," who recognised that it was the tactical not the technical training of the Prussian artillery which was chiefly at fault in the Austrian campaign? "What," he asked, "is the use of an artillery

which makes capital practice indeed, but which is never in the right place?" Discredited during the war of 1866, the Prussian artillery officers set to work to re-model the tactics of their arm in accordance with the changed conditions of modern fighting. The result of their labours during four years was that in the campaign of 1870–1 the action of the artillery was the theme of universal admiration throughout the German army, and Count Von Moltke has himself acknowledged that the victory of Sedan was practically decided by the artillery alone before ever the infantry advanced.

Necessity for a thorough tactical training of artillery during peace.

The great lesson, then, which the war of 1877–8 has to teach is, that which the war of 1870–1 previously taught—viz., the necessity for a thorough tactical training of artillery during peace. However excellent the *matériel* may be, however scientific the teaching of the gunners, however perfect the equipment, unless the use of artillery in the field in conjunction with infantry be also studied, and constantly practised, the tactical power of the arm in battle will not be fully developed. Artillery badly handled and badly led is only an incumbrance to a commander. "Like the Queen at chess, it is either a source of great strength or weakness, according to the way we use it." We may depend upon it that this is the correct teaching of the last war, and that what Capt. May affirmed to be the case in 1866 is more than ever true now—viz., that "in the next war, that side will obtain an unconditional tactical preponderance which best knows how to make use of its artillery, or rather that side which does not put off this practice till the moment that the war commences; in fact, the side whose artillery has had the best tactical training."

THE

WAR BETWEEN RUSSIA AND TURKEY

IN ASIA MINOR, 1877.

Translated from "Löbell's Jahresberichte"

BY

LIEUT. J. M. GRIERSON, R.A.

The Armenian plateau—with its bare table-lands, its rocky and almost treeless mountains of a wild Alpine character, with an average height above the sea-level of from 1500 mètres on the table-lands to 3400 on the highest peaks; with its scattered population, which is only thick in the valleys of the Kur, of the Kars-Tchai, of the upper Araxes, of the upper Eastern Euphrates (Murad-Tchai), of the upper Western Euphrates (Karasu), and of the upper Djorokh—strictly confines the lines of operation to the few roads which are fitted for the movements of large bodies of troops.

These lines of operation, whose points of departure lie in the Caucasus province, are the following:—

(*a*) From the lower Rion valley by Fort St. Nicolai (the Russian frontier post), on the narrow coast-plain, through the Turkish forts Kintrischi and Tzikhedziri, to the fortified port of Batoum; from this, through the lower Djorokh and Tortum valleys, by Artwin, to Erzeroum. This last road is not available, however, for large columns.

(*b*) From Akhalkalaki, in the Kur valley, to the fortress of Ardahan; thence by Pennek and Olti to Erzeroum. (A second class road.)

(*c*) From Alexandropol by Kars, where the road divides into two, over the Soghanli Dagh, into the Araxes valley, to Ardost, where the two roads unite, and thence by Köprikui and Hassan Kaleh to Erzeroum. (A first-class road, which extends north-west to Trebizond and west to Erzingian.)

(*d*) From Erivan to the Turkish frontier fortress Bayazid, thence by Karakilissa to Erzeroum, the Araxes being crossed at Köprikui. (A road of the first class, being a part of the great commercial road from the Black Sea to the Persian Gulf.)

Besides, there are the following second and third-class cross-roads:—Between *a* and *b*, Artwin-Ardanutsch-Ardahan; between *b* and *c*,

Ardahan-Omer Aga-Kars; between *c* and *d*, Kars (by two roads), through Hadji Kalil or Ardost to Kagizman and Karakilissa.

Corresponding to those four lines of operation, the Russians formed four columns, viz.:—The Rion Column (*a*), was intended to capture the port of Batoum; the rising of the Abchasians, however, necessitated the formation of the Ingur Column. The Akhaltzikh Column (*b*), the Alexandropol Column (*c*), and the Erivan Column (*d*), had, after the taking of Ardahan, Kars, and Bayazid, Erzeroum as their objective. Erzingian and Trebizond may be considered as ulterior objective points. The tables in the Appendix show the total available strength and the composition of the columns.

(*a*) Rion Column.

The coast range of north-east Tazistan, whose steep slopes approach the sea, and so leave only a narrow plain, on the average 3 kils. broad, and at the foot of which runs the road from St. Nicolai to Batoum, is traversed at right angles, from east to west, by the short and deeply scored valleys of the Tscholok, Okschamuri, Adkova, Tchorok-Su or Kintrischi, and Tchakvistana. Between these run the spurs which extend in a north-westerly direction from the main range of the Kolova Mountains to the coast. These five spurs have almost everywhere steep and terraced slopes, covered in some places with thick woods, and the communications throughout them are almost useless for military purposes; they therefore offer as many formidable obstacles to the advance of the Russian armies as excellent defensive positions for the Turks, the most advanced of which is 40 kils. from Batoum.

On account of the want of Russian ships to oppose the Turkish fleet, which was stationed near Batoum to command the coast road, this latter was from the first impassable for the Rion detachment, and it had therefore to fight its way to Batoum straight across the hills.

General Oklobjio ordered his troops to cross the frontier in three columns on the 24th April. The right flank column (Colonel Prince Abaschidze) was to advance from Fort Nicolai on the frontier post of Lill, and there unite with the centre column under Col. Worontintsoff; the thus formed right column, under General Schelemetieff, was to reach the heights of Mukha Estate. The left column, under Major-General Denibekoff, was directed from the Tscholok frontier post also on Mukha Estate. Colonel Worontintsoff succeeded on the 25th April, after a short skirmish, in uniting with Prince Abaschidze, who had reached the rendezvous on the 24th without fighting. The advanced guard (2 battalions 161st Regiment, 2 sotnias Kutais Horse, 1 sotnia Jeisk Cossacks) had to clear the heights of Mukha Estate of the small Turkish force entrenched there before Maj.-Gen. Schelemetieff could take possession of it.

General Denibekoff had, after a slight skirmish, seized on the point of passage of the Okshamuri, and reached Legwa, south-east of Mukha Estate.

In the next few days the whole corps was concentrated in the camp of Mukha Estate, on the ridges between the Okshamuri and Adkova,

while the next ridge between the Adkova and the Kintrishi was occupied by the Turks, whose outposts were in a thick wood on the right bank of the Adkova.

General Oklobjio employed the time till the 10th May in the fortification of the camp, arranging his lines of communication, provisioning his camp, and pacifying the inhabitants, who gave in their submission in the beginning of May. From the 8th May there were indications of a constant strengthening of the Turkish forces, and of a *levée en masse* of the inhabitants, whose head-quarters were in the village of Khotzubani. This lies on the ridge between the Adkova and the Kintrischi, called the Perang Hills, and commands the slopes on the left bank of the Adkova, which the Turks had fortified.

The focus of insurrection was to be taken by the Russians on the 11th May. General Denibekoff was to attack Khotzubani from the front with five battalions and a mountain battery, while General Schelemetieff was to march with a smaller force down the right bank of the Adkova, cross it, and attack the enemy's position on its left flank. Before this turning movement had developed itself, General Denibekoff met with an unexpectedly stout resistance in the Adkova valley, which he overcame by bringing his artillery into action and advancing with the bayonet; a further advance on the slopes over the stream was, however, impossible. In the meantime, General Schelemetieff had completed his flank march and driven the Turkish advanced troops opposed to him over the Adkova; but his own advanced troops, which were advancing on the first terrace above the left bank, were, in turn, driven back to the river, till towards mid-day this detachment had to remain on the defensive, and repulsed several attacks on its right flank. The last of these was driven back by the centre of the detachment with such loss to the Turks that the offensive was resumed, and the first terrace on the left bank was captured. Till then Denibekoff had only been able to gain ground very slowly, but being reinforced by three fresh battalions from the camp, he made an attack on Khotzubani which the much-weakened enemy could not resist. The latter therefore drew off unpursued towards his left flank. Two sotnias detached on the extreme right flank during the action were shelled by the heavy guns of a frigate, but suffered no loss. The total Russian loss was 10 officers and 160 men; that of the Turks is unknown.

In spite of the blockade of the Black Sea, declared by the Turks on the 5th May, which during the whole campaign remained a dead letter, the Russian steamer "Constantine," from Sebastopol, appeared before Batoum on the 13th May, to attack the Turkish frigate lying in the roadstead with torpedoes. The four launches sent out for this purpose did not, however, succeed; some of them retired to the roadstead of Poti, the rest returned with the "Constantine" to Sebastopol on the 14th. This courageously-undertaken but unsuccessful attempt to weaken the Turkish fleet, which barred the coast road, failed to open it for the Rion army, and therefore General Oklobjio remained confined to the difficult uplands, in which it was all the more difficult for him to operate successfully, as the enemy's army was being constantly reinforced by regular and irregular troops, and the rising in Abchasia in his

rear reached such dimensions that he had to gradually raise the detached Ingur Column to eight battalions with the necessary artillery, and thus weaken himself.

Next, from the camp of Khotzubani, the greatest part of the district of Kabulet, lying between it and the sea, on the Perang Hills, was subdued, and on the 28th May Colonel Gurtschin succeeded, after a short skirmish, in crossing the Kintrischi and capturing the heights of Sameba on the left bank. This success, however, did not hinder the Kabuleti, who knew the strong support they might expect from the concentration of the Turkish troops in the camp of Tzikhedziri, from turning their submission into open rebellion, to crush which three columns were directed on the 1st and 2nd June on the villages of Zeni and Alt-Utschkova. The amount of resistance shown by the natives may be judged from the Russian losses on the two days—81 men.

The position captured on the 28th May on the left bank of the Kintrischi, could not be held, on account of its isolated situation, and the Russians had soon to withdraw to the opposite heights of Lower Sameda, all the more because the Turkish camp, which extended from Kwirike, where the Kintrischi leaves the mountains, by Dagan to Sameba, and completely commanded the left bank of the Kintrischi, was daily strengthened by fresh battalions from Batoum. While the part of the Turkish camp on the heights threatened the Russian front, and could resist an attack by the united Russian forces, it was possible that a strong Turkish column might push forward along the coast road from the lower part of the camp, which was supported by Fort Tzikhedziri, and enter the Adkova valley, so as to threaten the Russian communications. Major-General Denibekoff, who, after the detachment from the Rion Corps of General Alchasoff's (Abchasian) column, had taken command of the so-called Kabulet Column, determined to clear up the uncertainty about the enemy's strength and intentions by a reconnaissance in force, and prepared to support the main infantry attack by placing on his left, touching his centre, on the Lower Sameda Hills, $3\frac{1}{4}$ batteries of 9-prs., and on the right on the Stolovaia and Lesistaia Hills a 9-pr. and a 4-pr. battery, which were got into position, masked by a wood, between the 20th and the 22nd June.

Order of Battle for the 23rd June.

Major-General Denibekoff.

Left Wing.—Colonel Gurtschin.

Left Column.	Right Column.
Lieut.-Colonel Prince Tchavtchavatze.	Colonel Kozelkoff.
Gurian Georgian Legion.	1st and 4th Rifle Battns.
1st Battn., 164th Regt.	1st Plastuni Battalion.

Reserve.

2nd Battalion, 76th Regiment.
1st 4-pr. Battery, 41st Brigade.

Right Wing.—Major-General Schelemetieff.

Left Column.	Right Column.
Lieut.-Colonel Prigara.	Lieut.-Colonel Makeieff.
4th Battalion, 163rd Reg.	2nd Rifle Battalion.
4th Battalion, 75th Regt.	Kutais Legion.

Reserve.

Lieut.-Colonel Tereieff.
1st, 3rd, and 4th Battalions, 161st Regiment.
4th Battery, 41st Brigade.

General Reserve.—Colonel Butschikeff.

151st Regiment.

In the camp there remained the 3rd Battalion 75th Regiment, 1st Battalion 163rd Regiment, and both cavalry regiments.

At 6 a.m. the Russian left flank battery and at 7 a.m. the great centre battery opened fire, also, in the course of the forenoon, the unfavourably-placed right-wing battery; but it was soon perceived that they could do little or no damage to the four well-posted Turkish batteries, which were on higher ground, were more under cover, and had before and between them, on the terraces rising from the river, no fewer than seven rows of shelter-trenches. The Turkish army was about 15,000 strong. The artillery combat soon sank into secondary importance, as the results obtained by the Russian fire were small, and the Turks reserved their ammunition to repulse the infantry attack, which was begun by Col. Gurtschin at 9 a.m. The columns, descending through the thick woods, were much broken up by them, and, when they emerged from under cover of the trees on the bank of the Kintrischi, were received by such a well-kept-up and crushing fire that it was 4.30 p.m. before the columns were assembled on the left bank of the Kintrischi, for the assault of the shelter-trenches. By 7 p.m. Kozeloff's column had succeeded in capturing three rows of them; Tchavtchavatze had won a little more ground, in spite of the attacks of irregulars on his flank; still, the strength of both, even after the reserve had been drawn in, was so expended, and that of the enemy so little shaken, that a further advance was impossible.

Nor had General Schelemetieff more success against the Turkish left in the lower part of the camp, as his own battery could make no impression upon that of the Turks, which was armed with heavy guns and supported by the fire of a frigate. His infantry, therefore, could not advance beyond a position which they had captured at noon, and whence they kept up a combat of small-arms. As the Turks ceased firing along the whole line at 8 p.m., and as a counter-attack of the Turks during the night was not to be feared, on account of the impassability of the ground, General Denibekoff ordered the troops to bivouac in the conquered positions, as a retreat to the right bank was not advisable, intending to withdraw them to the camp of Khotzubani next morning, as the results of the fighting had convinced him that his forces were not sufficient to drive the Turks from their camp.

When the retreat of the Russian infantry began on the morning of the 24th, a large concentration of Turks was noticed opposite the right and centre of the Russians, which seemed to presage an attack. The batteries of the centre and right remained, therefore, in their positions, and the infantry retreated partly into the batteries, partly to the trenches in front of them, and the right wing was extended as far as possible by detaching the two cavalry regiments to the coast plain; the whole of Colonel Gurtschin's column was placed as reserve, in rear of the centre, as it was seen that the Turks were massing their troops in front of the Lesistaia and Stolovaia Hills and the battery on the left of them. Both the battalions left in camp on the 23rd June were brought up to support this battery. The Turkish attack on the above points was carried out with extraordinary bravery. The 2nd Rifle Battalion and the Kutais Legion, who defended the right flank, were thrown back

into the batteries. Four Turkish attacks, however, against the position on the right flank failed, the 1st Battalion 161st Regiment having come up; so that by 7 p.m. the enemy drew off unpursued to his former camp. The Turkish attack on the centre against Colonel Prigara's battalions was also at first successful, and three battalions of the 151st were brought up. These drove the Turks out of the batteries, but the latter established themselves within range, and, opening fire, awaited the arrival of reinforcements; but the second attack failed entirely, so that till evening they were only able to keep up a rifle combat. The left wing was also slightly attacked by the inhabitants, while the position of the two cavalry regiments was shelled by an ironclad without effect.

In expectation of a renewed attack, Denibekoff remained ready in his position on the 25th June; the Turks, however, did not attack, but remained so near the Russian position that when the Russian Sanitary Detachments advanced on the 25th to bury the dead, who were mostly Turks, they were much hindered in their work of humanity by the Turkish infantry fire.

Having now recognised the insufficient strength of his forces for offensive movements, and the weakness of the Khotzubani position in the midst of a hostile population, also in consideration of the eventual necessity of detaching more troops to Abchasia, General Oklobjio ordered the retreat of the Kabulet Column to the fortified camp of Mukha Estate. Without annoyance from the Turks, the retreat was begun on the 28th June, and on the 30th the entire army was concentrated in the camp.

(*b*) Akhaltzikh Column.

The crossing of the almost impassable frontier range of mountains, which attain 2300 mètres, during constant rain and wind, offered considerable difficulties to the Akhaltzikh Column, which advanced from Akhalkalaki. The advanced guard, which advanced by Karzakh and Zurzuna, reached Bekra-Kothun, 20 kils. east of Ardahan, on the 28th May. As no pacification of the inhabitants, who at once submitted, absorbed the strength or time of the column, two small detachments of cavalry were at once sent by different roads to Kars, to establish communication with the Alexandropol Column, both of which entered Zaim on the 1st May.

Ardahan lies in the valley of the Kur, which is 19 kils. long and 13 broad, at the foot of the hills which bound it on the east, and is the point of junction of the Akhaltzikh-Olti and Batoum-Kars roads. Till 1872 Ardahan had only a citadel and a town-enceinte; in that year a system of redoubts was created round the old worthless fortifications, viz:—On the right bank, in a semi-circle from west to east, Forts Mekhrab and Diuz, which were connected with one another, and the isolated Forts Akhali, Singher, and Kaz Tapassi, all lying in the valley and completely commanded by the strong advanced Fort Emir Oghlu, 3 kils. to the south-east on the Gülawerdi Hill. Opposite this, on the left bank of the Kur, on the height commanding it on the north-east,

lay the strongest work of all, Fort Ramazan, which was revetted and provided with bomb-proof cover. Next to it, on the west, in the valley, lay Fort Kaia Baschi—a well-traced bastioned earthwork; and lastly, the unimportant little Kudian Tchair redoubt. Except Fort Ramazan, no work had revetted ditches. Forts Singher and Kaz Tapassi were strengthened by flanking batteries. The town fortifications lie on both banks, the citadel being on the right bank.

Ardahan was garrison by 12 battalions of infantry and two field batteries. The armament of the works consisted of 76 guns of the most different patterns, of which at most one-eighth were rifled. The state of all the works was above the usual Turkish style; they were in good preservation, and relatively secure against an attack in force.

From the state of the fortress, General Devel saw, in a reconnaissance on the 5th May, that his weak force was neither strong enough for a blockade nor an attack by storm. Recognising this, and as it was necessary to be secure from attacks from the side of Ardahan, before the siege of Kars was begun, General Heimann advanced on the 10th May on Ardahan from the Camp of Zaim, with the 13th and 15th Grenadiers, 15th Dragoons, 1st Gorsko-Mozdok Cossack Regiment, 2 sotnias of irregulars, 3½ batteries, and 2 companies of the 1st Sapper Battalion. The column, which was accompanied by General Loris-Melikoff, reached Pankis, 9 kils. south-east of Ardahan, on the 13th May, after a four days' march by Djelaus, Tschatak, and Khaskiöi.

During the advance of the reinforcements, General Devel had thrown a bridge over the Kur at Ur, 12 kils. below the town; and an attempt of the garrison to destroy this bridge on the 13th was repulsed. On the 14th the telegraph lines to Olti were destroyed. The detachment which had arrived under General Melikoff was divided into two columns, while to General Heimann were also given 2 battalions 153rd Regiment, 1 sotnia of Poltava Cossacks, the 5th Battery, 39th Brigade, and 3 companies of the 3rd Sapper Battalion. General Devel's column consisted of the 156th and 2 battalions of the 153rd Regiment, the 2nd Terek Cossacks, the 3rd and 6th Batteries of the 19th Brigade, and the 5th Kuban Battery. The remainder of the cavalry were absent, reconnoitring to the north and west. On the 15th May the siege artillery arrived, and was at once, with much difficulty, brought into position against the Gülawerdi Hill and Fort Emir Oghlu.

In spite of the strength of the two principal forts, General Loris-Melikoff determined to risk the storming of them, as they were too wide apart to mutually support one another. If he succeeded in taking the weaker, Emir Oghlu, he would command from it the forts in the valley on the right bank, and those as well as the town could be taken with inconsiderable loss; if these results were attained, it was a matter of doubt whether the works on the left bank could defend themselves. Following out this general idea, Devel's column encamped opposite the foot of the Gülawerdi Hill, while General Heimann's were dislocated to the south of the town in the valley. The Gülawerdi Hill, to which a gentle slope rises for 2 kils. from the village of the same name, is crowned by Fort Emir Oghlu on a wide plateau. To the

right of it an entrenched camp for two battalions had been thrown up. From this camp, whose front was strongly protected by rows of shelter-trenches on the terrace-like slopes, which were swept by a redoubt on the flank of the fort, the approach to the fort was easier than from the proper front of the latter. The fort was armed with 10 guns and garrisoned by 4 battalions under the energetic Kastar Beg. In the camp a mountain battery was placed in a very favourable position. For the attack of this position General Devel distributed his troops as follows :—

Left Wing.	*Centre.*	*Right Flank Detachment.*
Colonel Makiejeff.	Colonel Prince Amiradjiboff.	
½ battalion 153rd Regiment.	3 battalions 156th Regiment.	2 sotnias Poltava Cossacks.
½ 3rd Battery 19th Brigade.	½ 3rd Battery 19th Brigade.	½ Kuban Battery.
	½ Kuban Cossack Battery.	

Reserve.	*Demonstration against Fort Ramazan.*
	Major-General Oreus.
1 battalion 156th Regiment.	1 battalion 153rd Regiment.
½ 6th Battery 19th Brigade.	2nd Terek Cossacks.
1 Sapper Company.	½ 6th Battery 19th Brigade.

At 6·30 a.m. the artillery of the left wing opened fire at 3500 mètres; and its effect being speedily visible, the infantry of the centre moved to the attack of the advanced shelter-trenches of the camp. The Turkish infantry, in spite of the noble example of their officers, would not wait to receive the attack, so that by 10 a.m. the highest of the three lines was captured by the 156th Regiment. After a short pause, the regiment advanced to storm the camp, which was evacuated by the enemy. In spite of the great effect of the siege artillery, which had been engaged since 8 a.m., on the guns of the fort, the 156th suffered heavily in the last-taken position from their fire, and the half Cossack Battery, which with great difficulty was brought up, was at once put out of action; the infantry had therefore to keep up the fire alone, at a distance of 750 mètres, till at 1 p.m. General Devel, putting himself at the head of the whole regiment, advanced to storm the fort, which was soon taken, after a feeble defence, at the first rush. In the fort was captured, besides the guns of position, a quantity of ammunition and provisions. The demonstration on the left bank led to no action. The total loss of the day was trifling in comparison with the results gained, 118 men being *hors de combat.*

In the night from the 16th to the 17th May heavy batteries were thrown up against the works of the south front, with the intention of so shaking their powers of defence by a bombardment of one day that on the 18th a storm might be attempted. At 3 a.m. the bombardment of the forts began, and as disorderly movements of troops took place immediately after the commencement of the fire, and as a panic seemed to have set in, General Heimann resolved to storm the works at once, for which purpose he formed the following columns :—

Left Flank Detachment.

Major-General Scheremetieff.
12 sotnias.
½ Cossack Battery.

Major-General Duchovski.

Against Forts Mekhrab and Diuz.
4th Battalion, 15th Grenadiers.

Against Fort Akhali.
2nd Battalion, 15th Grenadiers.
3rd Sapper Battalion.

From the Gülawerdi Hill against Fort Singher.

General Heimann.

Left Wing.
1st & 2nd Battns., 153rd Regt.

Right Wing.
1st, 2nd, and 4th Battalions, 13th Grenadiers.
4th Comp., 1st Sapper Battn.

Reserve.
3rd Battalion, 13th Grenadiers.
1st & 3rd Btn., 15th Grenadiers.

General Devel's column made a demonstration from the left bank against Fort Ramazan. At 6 a.m. the four columns advanced against the forts, none of whose garrisons tried to oppose the bayonet attack. The Turks fled to the town in the greatest confusion, with the Russian battalions on their heels. In the narrow streets of the town and on both bridges of the Kur, the upper of which was shelled by Scheremetieff's artillery, a fierce fight raged, during which the citadel was captured by the Russians. At 8 p.m., after the Russian battalions had been rallied, everything, as far as Fort Ramazan, was in their possession; but their cavalry, on account of the darkness, could only keep up a feeble pursuit of the fugitives, who fled in all directions. Fort Ramazan was evacuated on the night before the 18th without General Devel noticing it, so that on the morning of this day the whole fortress was in the power of General Loris-Melikoff. The loss of the Russians on the 17th was 300 men, while the Turkish dead found in the works numbered 1750; the further losses were not known.

By the taking of Ardahan, from which no important operations to the south-west could be undertaken before the capture of Kars, the greater part of the Akhaltzikh Column was made available for further operations, and set out for Zaim with the troops of the Alexandropol Column on the 21st and 22nd May, a sufficiently strong garrison having been left in Ardahan under Colonel Komaroff.

Komaroff razed the fortifications to the ground, and after he had been strengthened by the 152nd Regiment, and sent four battalions to the siege-corps at Kars, extended his patrols to the south and south-west. In the last days of May, Pennek—80 kils. south-west on the Olti-Erzeroum road—was reported ungarrisoned, upon which Komaroff, pushing forward a strong detachment on the Ardahan-Olti road on the 1st, occupied it on the 2nd June. About 4000 Turks had left the place when he approached, and retreated to Erzeroum, so on the 4th and 5th June he returned to Ardahan. The oppression of the Christian inhabitants in the districts of Ardanutsch and Artwin, 65 and 95 kils. from Ardahan, necessitated the despatch of a column of 1700 men to the former place. On the 27th June the advanced guard, four sotnias strong, was attacked at Khaut, 5 kils. from Ardanutsch, while on the 28th of June a Turkish force of 3000 men took up a position between Khaut and their line of retreat. The detachment concentrated next day, and by an attack on both flanks of the Turks succeeded in forcing them to withdraw northwards towards the Botza, and cut them off

from Ardanutsch. In the evening Komaroff occupied the abandoned Turkish camp at Ardanutsch. 1500 Turks tried to retake it, but withdrew without fighting to Artwin and Batoum, so that the detachment returned to Ardahan on the 1st July.

(*c*) Alexandropol Column.

For the protection of the frontier towards Alexandropol, the Turks had pushed forward a feeble cavalry cordon to the Arpa Tchai, whose isolated posts partly surrendered to the strong advanced guard of Russian cavalry, partly tried to oppose its advance; an infantry brigade, pushed forward to Hadji Vali, 30 kils. east of Kars, also withdrew on that fortress. The Russian cavalry was pushed forward 15 kils. to the Kars Tchai, while the main body bivouacked at Tikhnis and Molla Mursa, a few miles over the border. In the further advance the main body of the advanced guard quitted the northern of the two parallel roads leading to Kars, which they had hitherto followed, between which the rocky Karajal and Karakuzu Mountains rise east of the Kars Tchai, and advanced on the southern road to Pulvaran, 27 kils. east of Kars, while the other part remained halted on the Kars Tchai, and the main body of the column, which had only advanced a short distance to Kizil-Tchaktchak and Argin, remained there on the 26th till a bridge was thrown over the river at Jamuschli. On the 27th the cavalry reached Subotan and Hadji Vali, the main body crossed the Kars Tchai, and bivouacked in Kuruk Dara and Poldirvan, on the north slope of the Karadjal Dagh. This ground, which was admirably fitted for an *etappen* station and a position to cover a retreat, was fortified and occupied by a permanent garrison, while on the 28th April the main body marched off in two columns to the north-east, to occupy a camp at Zaim, on the left bank of the Kars Tchai, 21 kils. north-east of Kars, which was to be fortified, and from which communications with the Akhaltzikh Column were to be opened, and in which the main body was to remain while large masses of cavalry were to raid to the west. The inhabitants of the district of Shoregel, which had hitherto been traversed, submitted, and in the course of time some volunteered to enter the Russian service, and from them three sotnias of Karapakas were formed, which did excellent service as *etappen* troops and gendarmes. Major-General Prince Tchavtchavatze now advanced towards the south and west of Kars from Hadji Vali, with 27 squadrons and sotnias and 2 batteries, and, marching by Vezinkoi and Magharadjikh, reached Khanlikoi, 11 kils. south of Kars, from which a mixed column advanced, but was repulsed by an attack of the 2nd Volga Cossacks.

This dashing raid of the masses of Russian cavalry made Mukhtar Pasha, who had assembled in Kars all the forces he could collect in this part of the country, fear that he would be shut up in that fortress with all his disposable troops, and that there would then be none to oppose the advance of the Russians on Erzeroum. He required a nucleus of regular troops for the Army of Operation, which was assembling in

Erzeroum, and therefore he left Kars by the Erzeroum road on the 28th April with eight battalions.

To turn the attention of the garrison of Kars away from Tchavtchavatze, a small detachment under Colonel Lazareff made a demonstration on the 29th April from the camp to within 7 kils. of the fortress, without bringing on a fight. It now seemed necessary to provide for the cavalry, who were still pressing westwards, a rallying point to the south of Kars. On the 29th, therefore, General Heimann marched with three Grenadier regiments (the 13th, 14th, and 16th), and five batteries to Khalif Oghlu, 15 kils. east of Kars, and on the 30th to Vezinkoi, 15 kils. south-east of the same place. Prince Tchavtchavatze had in the meantime pushed forward two separate columns, one under Major-General Loris-Melikoff towards the Kars-Olti road, which was reached at Soigudli, 18 kils. west of Kars, and upon which the column advanced on the 29th April by Latchgerd as far as Zeledji (32 kils.) without meeting the enemy. The column of Colonel Malama was more fortunate, as, in crossing the Kars-Erzeroum road, it came upon Mukhtar Pasha's army in retreat, which it soon forced into complete confusion. If was only at 11 p.m. that the Turks succeeded in making a stand at Yerischen, 53 kils. south-west of Kars.

The main body, under Prince Tchavtchavatze, had advanced to Tikna, 18 kils. from Kars, on the *chaussée* to Erzeroum. On the 30th April the two columns returned to the main body, and the whole marched by Khanlikoi, where there was a trifling skirmish with a sortie from Kars, to General Heimann's bivouac at Vezinkoi. Some regiments had in 48 hours marched 110 kils., during part of which time they were in contact with the enemy, and all the time on bad mountain paths. General Heimann now returned with his column to the camp at Zaim, taking with him two regiments of cavalry and a battery, while Tchavtchavatze remained at Vezinkoi with 17 squadrons and a battery. The next care of the head-quarter staff was to fortify the camp, to establish communications to the rear, to bring up the siege artillery, and to organise the *etappen* service. An endeavour was also made to establish communications with the Erivan Column, and for this purpose Colonel Count Grabbe was sent with 1 battalion, 10 sotnias, and 2 guns by Kulpi, and Major-General Loris-Melikoff with 10 sotnias by Vezinkoi and Khar to Kaghisman, on the left bank of the Avas, 60 kils. from Zaim.

On the 6th May both detachments entered the town, occupied it without fighting, and organised the Russian Government of the district; Grabbe remained there with a garrison, while Loris-Melikoff marched on the 7th May, reconnoitred to the west for two days, and then returned to Vezinkoi. A reconnaissance of the ground north of Kars, undertaken by Major-General Scheremetieff on the 7th May with 7 sotnias, through Topadjikh and Tschakmaur to Komkh, 6 kils. north-west of Kars, led to a short action on the Berdik Tchai, in which a Turkish sortie of four battalions and one battery tried to cut off the retreat of the detachment. With the object mentioned in *b*, the staff and a part of the column under General Heimann marched on the 10th to Ardahan, and the troops remaining in the camp were forced to remain inactive,

as they were too weak for field operations; but they concealed their weakness by means of constant reconnaissances made with a view of keeping the Turks continually on the alert.

The Turkish Government had made great exertions since 1865 to turn Kars into a powerful fortified camp, whose strength should correspond to its importance as a fortress barring the Alexandropol-Erzeroum road, situated on both banks of the Kars Tchai, which here, as in the whole of its course through the neighbourhood, breaks its way in a deep, rocky, and steep-sided valley through the rocky plateau. The town had formerly only the old citadel and the town-enceinte, the first of which completely commanded the three stone bridges. The citadel is built on a rocky conical hill, which forces the river to bend to the west, so that the eastern is the only assailable front. The fortifications consist of a high brick wall whose re-entering angles are flanked by half-towers; the crest line is 277 mètres long. The town-enceinte is worthless and partly in ruins. The outworks are constructed on modern principles, so far as the want of earth permits. The greater part of the works—which are hewn out of the rock—have no ditches, there being no earth upon the surface; that for the parapets had to be carted up, and on account of the great cost of this, few of the works are provided with traverses. It was also impossible to sink wells in the forts. The following is the list of detached works:—

A. Right Bank, or East Front.

1. Fort Arab, 2133 mètres N.N.E. of the citadel, on a spur of the Karadagh, commands the lower valley of the river. Lunette without ditches or traverses, closed by a defensible barrack; 368 mètres crest. In advance of the right face, a lunette with 190 mètres crest.

2. Fort Karadagh, on the top of the hill of the same name, 1200 mètres S.E. of No. 1, to command the Zaim and Alexandropol roads. Lunette without ditches, with a cavalier 6 mètres high on an isolated mound. Together, 920 mètres crest.

3. Fort Hafiz Pasha, between the Alexandropol and Vezinkoi roads (nearer to the latter), 1730 mètres from No. 2, and S. of it. A strong square bastioned fort, with a ditch, traverses on the main parapet, and a covered way; 960 mètres crest. 213 mètres from the S.E. Bastion, a redan-shaped earthwork, called Ekhali, with a crest of 70 mètres.

4. Fort Khanli, to protect the south front and the Magharadjikh road, 2840 mètres S.W. of No. 3. Lunette of bastioned trace with ravelin, ditch 3·5 mètres broad, 1·8 deep, covered way with traverses, and two small advanced redoubts. Defensible barrack at the gorge. 1305 mètres crest.

5. Suvari Lunette—an unimportant work barring the upper valley, 1545 mètres N.W. of No. 4.

B. Left Bank, or West Front.

I.—*Inner Line.*

6. Tschim Lunette; a work without a ditch, 900 mètres N.E. of No. 5. Close to the south of the Temur Pasha suburb, on a rock, at the foot of which the river takes a bend to the east, and which commands the upper valley.

7. Fort Veli Pasha, 900 mètres W. of the citadel, 1226 mètres N.W. of No. 6 on the southern Tschakmak Hill. Irregular closed bastioned work. Ditch 6·3 mètres broad, 2 deep, with defensible barrack. 200 mètres crest.

8. Inglis Tabia, 1706 mètres N. of No. 7. Lunette with ditches like No. 7, only for infantry.

II.—*Outer Line.*

9. Fort Techmas, 2000 mètres W. of No. 6, on a spur of the Tchorak Hills, to command the Erzeroum road. An irregular closed bastioned fort, with 474 mètres of crest.

10. Fort Tikh Tepessi, 533 mètres W. of No. 9, in a commanding position on the S.W. spur of the Tchorak Hills, commanding the Olti road. A four-sided bastioned redoubt, with ditches 2·5 mètres broad and 2 deep. N.W. of it is the advanced Ai Tabia redoubt. Together, they have a crest line of 316 mètres.

11. Laz Tepessi or Tschackmach batteries, on the most commanding position of the whole north front, 1200 mètres N. of No. 10, 2000 N.W. of No. 7. Three batteries close to one another, with retired flanks, and respectively 81, 72, and 81 mètres of crest line. In front of them is a covered way for infantry with 71 mètres crest line.

12. Muchlis Tabia, for the same purpose as No. 1, 1100 mètres west of it and 1130 mètres N. of No. 8. An advanced lunette with 290 mètres of crest. 200 mètres N.W. of it, the small Kottuk redoubt.

The armament consisted of 100 rifled guns, mostly muzzle-loaders, and 54 smooth-bores. The strength of the garrison necessary for such a fortress, whose outer line had a circumference of 16 kils., should be at least 25,000 men, which, however, at this time were not there. There was only bomb-proof cover for 3000 men, and bomb-proof magazines for supplies for four weeks. The strength of the forts lay in their excellent positions, but their construction showed, almost invariably, weak points. An assailant would find in the rocky soil scarcely a single place fit for the opening of approaches or batteries, so that all kinds of siege works have to be undertaken under great disadvantages.

General Komaroff began his reconnaissances on the 13th May by a demonstration against Fort Arab, with 1 battalion, 4 sotnias, and 1½ batteries, in which the troops captured without loss a large number

of cattle. The wish to capture the rest of the herds became so strong that it had to be satisfied by a reconnaissance in force against the east front on the 16th May. General Komaroff advanced with the 16th Grenadiers, a battalion of volunteers of the 14th Grenadiers, the Daghestan Cavalry Brigade, 2 sotnias Alexandropol Irregulars, 1 sotnia of Karapakas, and 2 batteries against Forts Karadagh and Hafiz Pasha; the 14th Grenadiers, 17th Dragoons, and 2 batteries remained in the camp at Zaim, while both the Volga Cossack Regiments had gone into bivouac on the 10th May at Khalif Oghlu on the Alexandropol road, to keep open communications with Prince Tchavtchavatze in Vezinkoi. The three irregular sotnias tried to capture the herds, which were in the pastures between the forts, but were driven back on the Daghestan Brigade by two cavalry regiments which debouched from Fort Hafiz, on which several fruitless attacks were made by the brigade. At 2 p.m. eight battalions with artillery debouched from between the forts, and began to press back the Daghestan Brigade. At this time the Russian troops which had been left in the camp came up, marching to the sound of firing. The 14th Grenadiers, with its volunteer battalion, and both batteries were placed opposite Fort Karadagh, while the 17th Dragoon Regiment moved to the left flank to support the Daghestan Brigade. The above-mentioned movement was hardly completed, when, as unexpectedly as the troops from the camp, both the Volga Cossack Regiments came up at a gallop from Khalif Oghlu, and at once charged the Turkish cavalry, which withdrew into the intervals between the battalions. At 5 p.m. the action was broken off. The loss of the Daghestan Brigade and the irregulars was 81 men; the commander of the brigade, Major-General Prince Tschelokaieff, was, in the last moments of the battle, mortally wounded.

On the 24th and 25th of May the troops detached to Ardahan returned to the camp of Zaim along with the battalions given over by General Devel.

On the 25th May the Turks made a sortie to the south, directed against the Cossack Division in camp at Magharadjikh, but it was easily repulsed by the latter. By degrees it was ascertained that the Turks had retreated to the Soghanli Dagh, were entrenching themselves there, and were sending troops southwards across the Araxes against the weak Erivan Column. To stop this, Loris-Melikoff moved with the entire Grenadier Division to Hadji Khali, 15 kils. from Kars, on the 29th May, and thence pushed Prince Tchavtchavatze forward with part of the Dragoon Division and the 2nd Daghestan Cavalry to Ardost, on the Kars Tchai. On the night from the 30th to the 31st the latter surprised 4000 Turkish cavalry, who had bivouacked without taking measures for their safety at the point (8 kils. west of Ardost) where the two roads which lead over the Soghanli Dagh separate. These were completely dispersed, and the 4th Squadron of the 16th Dragoons took 2 guns, 4 ammunition wagons, and 2 standards. The Russian loss was only 37 men, while the Turks left 83 dead. Loris-Melikoff now pushed forward part of his cavalry on the southern road towards Mezingerd, while he moved to Ardost with the 2nd Grenadier Brigade and thence sent detachments across the Kars Tchai to the

chaussée as supports for the cavalry. The remainder of the troops he sent back to the camp before Kars, from which General Devel had in the meantime reconnoitred the north-west front of the fortress without being disturbed by the enemy. The camp of Zaim was now broken up, and the troops encamped on the heights west of Kars at Aravartan, Bozgana, and Kogali, and outposts were thrown out towards the west front and the northern part of the east front, under the protection of which the siege works were commenced. On the 8th June the investment was completed, and on the 9th the north front was personally reconnoitred by the Grand Duke Michael, who had moved his headquarters to Kurukdara. On the 12th June the Turks opened a purposeless fire from the west front, and on the 15th an energetic sortie was made. At 3 a.m. the Turks advanced from Tikh Tepessi and Laz Tepessi with 9 battalions and 2 batteries, and at the first rush drove in the Russian picquets and captured the Tschiftlik heights, 6 kils. west of the forts and 4 from the camp at Aravartan. Four battalions of the 13th and 14th Grenadiers kept up a dropping fire against them till the cavalry from Kogali attacked the Turkish left flank, against which also 2 battalions of the 13th Grenadiers with a battery were sent. The Turkish advance was brought to a standstill, and finally they retreated, followed by the 17th Dragoons. The total Russian loss was 118 men; that of the Turks about 550. In the night from the 16th to the 17th June, 5 batteries, armed with 25 guns and mortars, were opened, and on the morning of the 17th the bombardment of Forts Muchlis, Arab, and Karadagh began, and was continued till the 23rd with small loss, and was hardly replied to. There was an unimportant sortie on the 22nd.

The cavalry, which had been pushed westwards as far as Mezingerd, being opposed by a concentration of fresh hostile troops, were not able to prevent Mukhtar Pasha—who, by drawing troops from Europe, had raised his army to 35,000 men—from pushing forward a part of his forces on the Bayazid Road; the Erivan Column would therefore have failed in its object if an advance on Erzeroum were not carried out by the main army, so as to threaten Mukhtar Pasha's line of retreat and cause him to withdraw the troops he had detached towards Bayazid. Loris-Melikoff had therefore to operate on Koprikoi, the point of passage of the Aras, but could not use the road leading thither in a south-easterly direction from Mezingerd, by Khorassan and Ardost, till Ismail Pasha had been driven from his entrenched position at Zewin on the northern parallel road. The great tactical strength of the position of Zewin and the uncertainty as to the strength of the enemy—reckoned at 10,000 men at least—forced Melikoff to concentrate the entire Grenadier Division at Mezingerd, and its last échelon entered the camp there on the 24th June.

Ismail was encamped with about 19,000 men in a very strong position on the rocky heights on the right bank of the Zewin Tchai, in front of which the slopes falling to the river, in form of terraces and exceptionally steep and stony, and without cover for an assailant, were swept by four batteries which were connected by two (in places three) rows of shelter-trenches; behind the ridge the open and rolling

ground gave exceptional advantages for fortifying the camp, and for the placing under cover of strong reserves, which, though concealed, were close to the fighting line. The steep and deeply cut valley of the Khani Tchai, which falls into the Zewin Tchai, divided the isolated but commanding position of the right wing from the main position. This was rendered almost impregnable by the formation of the ground, and on it were posted two mountain batteries which completely commanded the ground in front and on the flanks. The centre was strengthened by a redoubt and a battery, which last was also intended to sweep the main road. The left flank was the weakest, but was still quite defensible, and was commanded by the central position, and its flank was covered by a river which was absolutely impassable.

On the opposite (left) bank, the reverse slope of a ridge permitted the Russian columns to concentrate unmolested, and through its deeply-cleft valleys infantry could debouch on to the river Zewin, ford it, and then reach the first steep slopes of the enemy's position quite unobserved up to a certain point. It was almost impossible to take artillery over to the right bank; it could, however, support the attack from the ridge on the left bank, being on the same level as the Turkish batteries, and 3600 mètres from them.

General Heimann, acting under orders from General Loris-Melikoff, ordered the troops to be under arms at 3.30 a.m. on the 25th June, except 5 companies, 1 sotnia, 1 battery, and 3 sapper companies, who were to remain as baggage guard in the camp of Mezingerd on the Mellidooz brook, and advance towards the above-mentioned rendezvous, which was reached at 9 a.m. by the cavalry, and 12 noon by the infantry. The cavalry had first to drive the enemy's weak outposts over to the right bank. After the infantry had had a rest of two hours, Heimann formed his troops for the attack as follows:—

Left Flank Detachment.	*Left Wing.*	*Centre.*
Major-General Prince Tchavtchavatze.	Major-General Cederholm.	Major-General Komaroff.
16th and 17th Dragoons. 1st and 2nd Volga Cossacks.	16th Grenadiers. 4th Battery. 1st and 2nd Daghestan Cavalry Regiments.	14th Grenadiers (except five companies). 15th Grenadiers. 6th Battery.
Tschetschna and Alexandropol Cavalry Regiments. Gurian Legion. Kuban and Terek Batteries.	4 battalions, 8 sotnias, 1 batt.	$6\frac{3}{4}$ battalions, 1 battery.
26 sotnias, 2 batteries.	Infantry to attack enemy's right; cavalry to keep up connection with left flanking detachment.	To attack enemy's centre.

Right Wing.	*Right Flank Detachment.*
Major-General Avinoff.	Kisliaro-Greben Cossacks.
13th Grenadiers. 1st, 2nd, and 3rd Batteries.	3 sotnias.
4 battalions, 3 9-pr. batteries.	To cover the right flank.
Remain on left bank, shell the centre of the enemy's position, and support the attack of the centre column. Infantry to cover artillery.	

Prince Tchavtchavatze was to turn the Turkish right by a road 32 kils. long and threaten their line of retreat; also to keep a look out

towards Khorassan, where Mukhtar's cavalry were said to be. They were to march at 1 p.m. No general reserve was formed.

At 2 p.m. the left and centre columns advanced and crossed the river while the artillery on the right opened fire.

The left wing climbed the first hill and drove the Turks from two rows of shelter-trenches, and then began a small-arm fire to prepare for an attack on the next hill, which was defended by three rows of shelter-trenches, in which the batteries hitherto brought into position co-operated, and which were stormed by a bayonet attack. The mountain batteries, which still kept up their fire, were perfectly unassailable, because a gully with almost perpendicular sides lay in front of them. An attempt made by the troops on the extreme left to turn this obstacle was repulsed by the furious fire of the reserves of infantry and artillery. A slight support was afforded by the left flanking detachment on the extreme left towards 7 p.m. This detachment had had to contend with extraordinary difficulties, and at last, contrary to their expectations, found in front of them broken ground, cut up by fissures in the rocks, over which they had to attack, and in which cavalry and artillery were useless. The 17th Dragoons, both Cossack Regiments, and the Gurian Legion then dismounted, and commenced a purposeless small-arm fire, which they had to break off on the approach of twilight, when hostile columns appeared marching on the Koprikoi road (from Delibaba, hastening, under Mukhtar Pasha, to support Ismail. See section *d*).

In the centre, the two lowest rows of the enemy's shelter-trenches were captured at the first rush, under protection of the fire of the 9-prs., in spite of the heavy fire of the Turks. An attempt of the 6th Battery to come into action here failed, on account of the heavy fire. The 14th Grenadiers climbed the steep stony slope in front of the redoubt to from 40 to 80 mètres distance from it, and pressed on with the bayonet in close order. After great difficulties, they succeeded in assembling at about 20 mètres from the redoubt, under a murderous fire, but had to fall back under cover of the slope. The steepness of the slope may be judged from the fact that the killed and severely wounded rolled down it. A second attempt at a storm, this time more to the left, also failed before the salvoes of the Turkish front line and those of the reserves on the flank. On the right of the 14th, the 15th Grenadiers tried to press up the hill between the redoubt and the mitrailleuse battery, were repulsed, attacked again with the bayonet after a short fusillade, pressed into part of an unfinished breastwork for infantry, but had soon to retreat again under cover of the first ridge. To support this now almost defenceless regiment, two battalions of the 13th Grenadiers from the right wing were sent over the river at 6 p.m. These tried to turn the enemy's left, and pressed also into their first line, which was feebly defended, but were stopped and driven back by the repeated attacks of a numerous body of cavalry.

At last, at 7.30 p.m., a lull in the firing occurred, and soon it stopped altogether. A renewal of the Russian attack next morning seemed, after due consideration, impossible. The wearied troops who bivouacked on the battle-field that night were withdrawn from the left wing during

the night, and by daybreak the right wing had also left its position and covered the retreat, which was unmolested. The loss of the day, which fell almost entirely on the Grenadier Division, was 850 men, or from 9 to 10 per cent. of the effective.

The loss of the battle of Zewin, and the threatening of the retreat of the Erivan Column by the appearance of the Turks before Bayazid, mark the turning point of the operations of the first period. The junction of the Alexandropol and Erivan Columns, which would have been done in three days' march, could not now take place; the latter had to begin its retreat, and the former was compelled to do the same, by the advance of Mukhtar Pasha with a strongly reinforced army. On the 29th June Loris-Melikoff began his retreat on Kars from the Camp of Mellidooz, and on the 9th July had to raise the siege of the former place before the advancing Turks. The siege artillery was mostly sent back to Alexandropol, but a part of it was used to arm the works at Kurukdara. The infantry withdrew first to Zaim, the cavalry to Hadji Vali. When Mukhtar advanced, the army had first to retire to the line Khalif Oghlu-Bulanach-Aladja, and finally to Ketschis-Kurukdara-Kadiklar-Yilanli. On the 20th July these positions were taken up, and for some time the armies remained quiet, observing one another.

(*d*) Erivan Column.

The Turkish frontier town Bayazid, to which an old but strong citadel gives a certain worth as a fortress, lies in the centre of a semicircle extending to the east, whose northern part is formed by the Russian, its southern and eastern by the Persian frontier. The Russian frontier runs off at a tangent from the northern part of this semicircle, and runs 55 kils. to the west before it turns up towards Alexandropol. Parallel to the former section of the frontier line runs the road from Bayazid by Karakilissa to Erzeroum, 22 kils. south of the line.

The Ararat Mountains, upon which, north-east of Bayazid, the point of junction of the three frontiers lies, prevent, by their want of roads, the advance of Russian troops from this side, so that an advance on Bayazid can only be made from the north, and if this be combined with an invasion further west, to cut off the retreat of the garrison to Erzeroum, there is nothing left for it but to retire into the territory of the Kurds on the Lake of Van.

General Tergukasoff, who had concentrated his corps at Igdir, 45 kils. north of Bayazid and 23 from the frontier, sent an advanced guard forward in two columns towards the border on the 27th April, to make the road fit for troops. On the 28th he followed with the left column of the main body, marching by Orgoff direct on Bayazid, while the right column, under Lieut.-Col. Schimscheff, moved in a south-westerly direction by Kudjach, to strike the caravan route. A deputation of the inhabitants of Bayazid was sent to the left column to state that they wished to submit to the Russians, but were hindered from so doing by Ali Kiamali Pasha, the Governor of the district, who held the town with 2 battalions, 5 squadrons, and 2 mountain guns. On the

29th, Colonel Fillipoff reconnoitred from Karabulach, 18 kils. north-west of Bayazid, to close up to the town, from which the Turks withdrew to the south on the 30th without fighting, upon which Tergukasoff took possession of the place, but not before the inhabitants, in revenge for past oppression, in the short interval of anarchy, had plundered and destroyed all Government property. Colonel Kovalevski was appointed Commandant and Civil Governor, and a garrison (two battalions 74th Regiment, half-battalion 73rd Regiment, and two guns) left in the place; while the left column advanced 10 kils. to Arsit, and the right moved to Missum and Karum, 22 kils. north-west of Bayazid, still marching southwards, and remained there till the 8th of May. This time was necessary for the organisation of the civil administration, the bringing up of *matériel*, and the arranging for supplies. On the 8th, both columns advanced to the south-west, intending to unite at Diadin, 30 kils. west of Bayazid or the Erzeroum road. Considerations of supply must have kept the corps idle till the 13th May, for it was only then that a strong advanced guard under Major-General Prince Amilochvaroff was thrown out 13 kils. to the west, which reached the old convent of Surp Owhanes, after driving in a few weak Turkish patrols. The advanced guard ascertained that at Karakilissa, 45 kils. west of Surp Owhanes, two Turkish battalions, with 500 Kurdish cavalry and two guns, had taken up an advanced position, a day's march behind which, on the south slopes of the Agri Dagh, commanding the high road from the north at Topra Kaleh, four battalions and half a battery were bivouacked. The main body advanced on the 15th May to Surp Owhanes, but had to stop their further advance and give up the idea of attacking even this small force, because to the south of Bayazid movements of the enemy's troops were reported, the object of which had first to be ascertained.

Ali Kiamali Pasha had succeeded in raising the Kurd Tribes against the Russians, from Bazid Aga, 44 kils. south of Bayazid, and had concentrated about 4000 of them in the Sukh-Su valley, while he awaited further reinforcements from Van; he had also drawn in the regular garrison of Van (three battalions and nine guns), so that Bayazid and the Igdir road appeared seriously threatened when Prince Amilochvaroff entered the town with the advanced guard on the 16th May, having done 58 kils. in a forced march of 12 hours. After having taken measures for the defence, he made a reconnaissance on the 19th May to Kazi Gil, 30 kils. south of Bayazid, without meeting any enemy, who for some time undertook no forward movement, so that a weak detachment seemed sufficient for the security of the place, and there was now no reason for delaying the march of the main column. On the 26th May Tergukasoff sent a reconnaissance against the slightly fortified position of Karakilissa in the upper Alaschgerd district, by which the strength of the Turks was judged at 12 battalions with a few guns. The advanced troops in Karakilissa withdrew on the 4th June before the Russians, on the 9th evacuated Topra Kaleh, and on the next day Zeidikhan, on the high road, to concentrate in a very favourable position on the Dhrom Dagh, in which four battalions of reinforcements had arrived. Here, at Dieligol and Taghir, the road crosses the water-

shed, 2000 mètres high, of the Upper Euphrates and the Aras, to the west of which, at Delibaba, 20 kils. from Taghir, the Passin plain is entered, in which the Aras is crossed at Kuprikoi, 40 kils. west of Delibaba, and thence the road leads along the left bank to Erzeroum by Karsankaleh. On the 15th June the Russian advanced guard fell in with the Turkish outposts in front of Taghir, whose main position was at the summit of the road, and admirably organised for defence. There were only seven guns in position, and the steep rocky slopes only permitted of 3000 men being brought into line in the entrenchments. The knowledge of having an overpowering superiority in artillery—30 guns—and the fact of the continual retreat of the Turks hitherto, induced General Tergukasoff to attempt the attack with the six battalions of the 73rd and 74th, and the 3rd Rifle Battalion, which he had with him. On the 16th, at 7 a.m., he opened fire from two batteries, and ordered two battalions of the 73rd to advance to the right and two of the 74th to the left of the road, and succeeded, after a hard struggle of six hours—more with the difficulties of the ground than with the enemy, 16 battalions strong, who merely threw away their ammunition—in forcing the Turks to retreat. An attempt to turn the enemy's right with cavalry failed, on account of the difficulty of the ground. The Turks left 100 killed and wounded behind them, while their commander, Achmed Pasha, was killed. The loss of the Russians was only 150 men.

The 149th and 150th Infantry Regiments had had to be left in the interior of the province at the beginning of operations, and only two battalions of them and a few sotnias had advanced as far as Orgoff, under Major-General Kalobalai Khan, where they remained ready to support the garrison of Bayazid. The danger to this place from the Lake of Van seemed to have completely cleared off, when suddenly on the 14th June a mass of Turks and Kurds, stated at 13,000 men, appeared at Temporis, 18 kils. south of Bayazid, and drove in the weak outposts on the 17th. On the 18th there was a general attack on the town, which the Russians had to evacuate. They retreated into the citadel, which was at once invested and bombarded by the Turks.

An attempt to relieve the garrison made by Kalobalai Khan on the 25th June was repulsed at Karabulak; so that now the garrison had to hold out without hope of relief, which, on account of the want of food, was more desired every day.

These threatening occurrences in Tergukasoff's rear, and also the weakness of his detachment opposite an enemy who was constantly receiving reinforcements, and who, after the battle of the 16th June, had only retired 15 kils. to Delibaba, hindered his further advance.

On the 21st June a reconnaissance, sent out under Col. Medvedovski, of two companies and seven sotnias to the north of Taghir, came, at Hassan Beg, on the nothern parallel road to Delibaba, on a strong hostile column—Mukhtar had personally brought up eight battalions to Delibaba to stop the retreat—who deployed at once on and to the south of the road, and advanced to attack with at least twenty battalions and a numerous cavalry. Medvedovski managed to hold his own till the arrival of the 1st Battalion 74th Regiment and the 4th Battery,

while to his left Colonel Borelius brought up the Rifle Battalion and the 3rd Battery into a position on the *chaussée*, and Colonel Schack coming up a little later with the 4th Battalion 73rd Regiment, the 3rd Battalion 74th, and 1½ batteries, filled up the gap in the centre. The Turks attacked both flanks in great force. The left wing, strengthened by the 1st Battalion 73rd Regiment and the horse artillery battery, repulsed two infantry attacks—the last of them with the bayonet—and finally, so beat back a cavalry charge directed against them that the retreating cavalry carried away part of the infantry of the Turkish right wing. The weakness of the Russians prevented an active pursuit. The Russian right wing defeated all the attacks by the superiority of its artillery, so that towards evening it was possible to make an energetic counter-attack from the centre. About 10 p.m. the battle ceased, after which both armies bivouacked in their positions. The Russian loss was 454 men. On the 22nd June the Turks retreated; not on account of their defeat, but in order to send a part of their forces to strengthen Ismail Pasha from a position where the Russians could not notice their departure. Tergukasoff did not remark this, and remained in Taghir, having withdrawn from Hassan Beg. On the 26th June he learned the result of the Battle of Zewin and the reinforcement of his direct opponent, and therefore determined upon a retreat, which began on the 27th, taking with him under escort a number of Armenian families, to save them from the excesses of the Turkish irregulars, by which means his movements were rendered very slow. In his retreat, he reached Zeidikhan on the 28th, Karakilissa on the 30th, Surp Owhanes on the 2nd July, a pass on the frontier on the 4th, and Igdir on the 5th of July.

After a short rest, Tergukasoff advanced to relieve Bayazid, and on the 10th July stormed the heights in front of the town, and relieved the almost exhausted and small but brave garrison, which, during the three weeks' siege, had lost 30 per cent. of their strength. The town of Bayazid, destroyed and plague-stricken, had to be given up. Tergukasoff then retreated to Igdir, to reconstruct and reinforce his corps, leaving detachments to observe the three border passes.

(*e*) The Rebellions in the Caucasus.

The Grand Duke Michael could not use all his troops for the invasion of Armenia, as the excitement of the Mohammedan peoples in the Caucasus reached a high pitch and required troops to keep it down. The 20th Division was therefore left behind in the Terek District, principally in the south-east part of it—the Greater and Lesser Tschetschna—while the 21st Division had three regiments in Upper and one in Lower Daghestan. In the Soukhoum military district, Abchasia, the Ingur Column was formed. There were also disposable for the defence of the country from 20 to 30,000 men, mostly local troops in the various forts. In spite of this seemingly sufficient number of troops, the Turks succeeded in raising a rebellion in the three above-mentioned provinces. In the Tschetchna the people only rose, as also in

Daghestan, while in Abchasia the Turkish fleet landed several thousand of the emigrant Circassians who had settled in Bulgaria, and there become brigands, and by the addition of this warlike element the rebellion attained such dimensions that not only was the weak Russian force in the district endangered, but it exercised a disquieting influence on the operations of the Rion Column.

Without going into details, the following combats took place in Abchasia:—On the 5th May seven Turkish ships bombarded Poti, and then went further north to Gudanti, south of Soukhoum, bombarded it on the 12th, and landed 1000 Circassians, against which General Kravtschenko sent a few sotnias from Soukhoum. On the 13th May two ships bombarded Otschemschiri, 50 kils. south-east of Soukhoum, and on the 14th six other ships appeared before Soukhoum and tried to land a number of Circassians under cover of a bombardment of the town, which were repulsed by Kravtschenko. An attack by the rebel inhabitants, and a second bombardment on the 16th, forced Kravtschenko to withdraw from the town to the left bank of the Madara, south-east of Soukhoum, where he was completely surrounded by the insurgents till he was extricated by reinforcements which arrived on the 24th May. After a bombardment of Cape Adler, from the 17th to the 19th May, from seven ships, they succeeded in landing 3000 Circassians there on the 23rd May, before which the Kuban Cossack Battalion had to withdraw to Sotscha. Kravtschenko had to retire also to the Kodor, after an unsuccessful fight at Agansk on the 22nd; so that by the end of May the whole coast from Cape Adler to Cape Drandy was in the power of the insurgents, and special measures had to be taken by the garrisons of the passes to prevent the insurrection from spreading over the mountains into the Kuban district. In the meantime the first troops from the Rion Column, under General Alchasoff, arrived on the Kodor, on the 30th May repulsed an attempt of the insurgents to cross to the left bank, and on the 1st June beat off two monitors which attempted to land troops at Sotscha. On the 13th June Alchasoff repulsed an attack by land and sea on Ilori, at the mouth of the Galizza, south-east of Otschemschiri. For combined operations, Alchasoff took over on the 15th June the command of all the troops in Abchasia and Kutais, and still was not able to gain any serious success. On the 19th June he found Otschemschiri unoccupied by the enemy, but he had soon to march inwards, up the Mokurli valley, to attack the insurgents at Mergula and Mokwa, on the 23rd. He could not follow up his success, however, as he had to return at once to the coast to retake Otschemschiri, which had been reoccupied by the insurgents. This he did on the 27th. In the course of the month of July Alchasoff remained in a fortified camp at the mouth of the Galizza, where he repulsed attempts at landing on the 13th and 20th. After a long period of inaction, he advanced on Soukhoum on the 19th August, and found the line of the Kelasuri, 5 kils. south-east of it, occupied, and the passages guarded, so that he could not advance against Soukhoum, which was strongly fortified. On the 23rd, however, he succeeded in storming the Gudanti position, which was held by Abchasians and regular Turkish infantry, so that he won a favourable base for further operations against Soukhoum. After

General Babitsch had arrived on the 24th with fresh troops, combined operations were begun against the town on the 28th, the result of which the garrison did not wait for, but embarked on the 31st August, taking with it 3000 emigrants. After the head-quarters of the insurrection had fallen into the hands of the Russians, from the beginning of September, the rebellion gradually died out in Abchasia. Besides the material damage and the emigration of the inhabitants—both of which the insurrection had caused in the district—Russian troops, to the strength of a whole division, were for four months withdrawn from the Army of Operations by it.

The insurrection in the Terek and Daghestan districts, which extended over a far larger territory than Abchasia, could not be directly supported by the Turks, but the insurgent element in the country itself was much stronger than that on the coast of the Black Sea. It suffices to mention that single risings during the month of May in different places were promptly and powerfully suppressed, so that in both districts quiet appeared to be restored in June. When the reverses of the Army of Operations were known, rebellion broke out again, and in some places grew, till in August it had attained to some importance; so that it required energetic efforts till the end of the month to repress it a little. Its progress and growth will be mentioned in the narrative of the Second Period of Operations.

For the sake of continuity we have narrated the events in Abchasia and on the Caspian till the end of August—*i.e.*, beyond the First Period of Operations; this itself was closed by the retreat of all the Russian columns of operation to and over the border. Mukhtar Pasha was at the height of his success. He had first withdrawn in time before superior forces, and had not opposed their march, which was retarded by difficulties of supply and the bad state of the roads, till he was sufficiently strong, and then he used his numerical superiority to press his opponent back over the frontier, leaving him only the one unessential point, Ardahan, in his hands. With this, however, his activity was completely exhausted, for he neglected to take advantage of the bad state of the Russian army to assume the offensive energetically. The Caucasus army could then only, considering the state of affairs in the interior, remain on the defensive on the frontier and await reinforcements.

Note I.

Order of Battle of the Mobile Troops of the Army of the Caucasus, April 24th.

Caucasus Grenadier Division.—Lieut.-General Prince Mouravieff, II.

1st Brigade.—Major-General Avinoff. 13th (Erivan), 14th (Grusian) Regiments.
2nd " Major-General v. Schack. 15th (Tiflis), 16th (Mingrelian) Regiments.
Caucasus Grenadier Artillery Brigade.

19th Division.—Major-General Komaroff, II.

1st Brigade.—Major-General Bronevski. 73rd (Crimea), 74th (Stavropol) Regiments.
2nd " Major-General Alchasoff. 75th (Sevastopol), 76th (Kuban) Regiments.
19th Artillery Brigade.

20th Division.—Lieut.-General Heimann.

1st Brigade.—Major-General Wiberg. 77th (Tengin), 78th (Navagin) Regiments.
2nd " Major-General Nasvietevich. 79th (Kura), 80th (Kubarda) Regiments.
20th Artillery Brigade.

21st Division.—Lieut.-General Petroff.

1st Brigade.—Major-General Mouravieff. 81st (Apscheron), 82nd (Daghestan) Regiments.
2nd " Major-General Poltaravski. 83rd (Samur), 84th (Shirvan) Regiments.
21st Artillery Brigade.

38th Division.—Lieut.-General Tergukasoff.

1st Brigade.—Major-General Merchilevitch. 149th (Black Sea), 150th (Taman) Regiments.
2nd " Major-General Kusminski. 151st (Piatigor), 152nd (Vladikavkas) Regiments.
38th Artillery Brigade.

39th Division.—Lieut.-General Devel.

1st Brigade.—Major-General Zitovitch. 153rd (Baku), 154th (Derbent) Regiments.
2nd " Major-General Oreus. 155th (Kubin), 156th (Elisabethpol) Regiments.
39th Artillery Brigade.

41st Division.—Lieut.-General Oklobjio.

1st Brigade.—Major-General Schelemetieff. 161st (Alexandropol), 162nd (Akhaltzikh) Regiments.
2nd " Major-General Denibekoff. 163rd (Lenkoran), 164th (Zakatal) Regiments.
41st Artillery Brigade.

Caucasus Dragoon Division.—General Count Toulouse Lantree.

1st Brigade.—Major-General Loris-Melikoff. 15th (Tver), 16th (Nijni Novgorod) Dragoons.
2nd " ..... 17th (Siever), 18th (Pereislav) Dragoons.
13th and 14th Don Cossack Batteries.

Caucasus Cossack Division.—Major-General Scheremetieff.

Kuban, Caucaseus, Jeisk, and Gorsko Mozdok Regiments.
1st and 2nd Terek Cossack Batteries.

Troops not included in the Division.

I.—*Regular Troops.*

Caucasus Rifle Brigade.—Colonel Gurtschin. 1st, 2nd, 3rd, and 4th Battalions.
Caucasus Sapper Brigade.—Major-General Solovieff. 1st, 2nd, and 3rd Battalions.
Telegraph Park, Siege Artillery Park.

II.—*Cossacks.*

(*a*) Kuban Army.—1st and 2nd Poltava, 1st and 2nd Labin, 1st and 2nd Urup, 1st and 2nd Taman. 1st and 2nd Choper, 1st and 2nd Jekaterinobar, 2nd Caucasus, 2nd Jeisk and Uman Regts, 2 horse batteries.

(*b*) Terek Army.—1st and 2nd Volga, 1st and 2nd Kisliaro-Greben, 1st and 2nd Sunia, 2nd Vladikavkas, and 2nd Gorsko Mozdok Regiments. 1 horse battery.

(*c*) Infantry.—6 battalions Plastouni.

III.—*Irregular Troops.*

4 Daghestan, 2 Kutais, Akhaltzikh, Kurtin, Samursakan, Soukhoum, Tschetchna and Zakatal Regts.
3 Noble-Legions from Tiflis, Guria, and Kutais.
3 Alexandropol sotnias, Bortschalin and Tionetia sotnias.

Total Strength.

	War strength.	80 per cent.	60 per cent.
Regulars	170,000	136,000	102,000
Cossacks.....	25,000	20,000	15,000
Irregular cavalry ...	10,000	8,000	6,000
Totals.....	205,000	164,000	123,000

N.B.—The commanders changed so much during the campaign that those on the 1st Sept. only are given.

Note II.

Columns of Operation of the Caucasus Army—1st Period.

Commander-in-Chief, Grand Duke Michael.

Army of Operation in Armenia.

Commander, Gen. Loris-Melikoff. Chief of the Staff, Maj.-Gen. Duchovski. Comdg. Artillery, Maj.-Gen. Dubski. Comdg. Engineers, Maj.-Gen. Kerberg.

Rion Column (*a*). Comdr., Lt.-Gen. Oklobjio. Chief of Staff, Col. Kasbek.	Battalions.	Squadrons.	Batteries.
41st Infantry Division (ex 162nd Regiment)	12	0	6
2nd Brigade, 19th Division	8	0	2
151st Regiment	4	0	0
1st, 2nd, and 4th Rifle Btn.	3	0	0
1st Plastuni	1	0	0
2nd Jeisk, 2nd Kutais Cossack Regiments	0	12	0
Guria and Kutais Legions	0	8	0
2nd Battery 38th Brigade	0	0	2
2nd Sapper Battalion	1	0	0
Total...	29	20	10

Akhaltzikh Column (*b*). Comdr., Lt.-Gen. Devel. Chief of Staff, Col. Makieff.	Battalions.	Squadrons.	Batteries.
153rd and 156th Regts.	8	0	0
1st Poltava, 2nd Gorsko Mozdok Cossacks	0	10	0
Akhaltzikh Cavalry Regt.	0	4	0
3rd & 6th Batts. 19th Bde.	0	0	2
5th & 6th Batts. 39th Bde.	0	0	2
5th Kuban H. Art. Battery	0	0	1
3rd Sapper Battalion	1	0	0
Total...	9	14	5
152nd Regt. added after capture of Ardahan			

Alexandropol Column (*c*). Comdr. Lt.-Gen. Heimann.	Battalions.	Squadrons.	Batteries.
Caucasus Grenadier Divn.	16	0	6
Caucasus Dragoon Division (ex 18th Regiment)	0	12	2
Caucasus Cossack Division	0	22	2
2nd and 3rd Daghestan Cavalry Regiments	0	12	1
1st Urup, 1st & 2nd Volga, 2nd Vladikavkas Cossack Regiments	0	18	0
Alexandropol Cavalry	0	3	0
1st Kisliaro Cossacks	0	4	0
Tschetchna Regiment ... } Tiflis Legion ... }	0	8	0
1st Sapper Battalion	1	0	0
Total...	17	79	11

Erivan Column (*d*). Comdr. L.-Gen. Tergukasoff. Chief of Staff, Col. Fillipoff.	Battalions.	Squadrons.	Batteries.
1st Brigade, 19th Division	8	0	2
3rd Rifle Battalion	1	0	0
18th Dragoons	0	4	0
2nd Choper Cossacks	0	6	1
Kurtin and Zakatal Cavalry	0	10	0
4th Battery 38th Brigade	0	0	4
Total...	9	20	7

Columns in Interior.	Battalions.	Squadrons.	Batteries.
1. Ingur Column.			
162nd Regt. and 1 local battn.	5	0	0
2nd Labin Cossacks	0	6	0
Samursakan and Soukhoum Cavalry	0	8	0
6th Battery 20th Brigade	0	0	1
Total...	5	14	1
2. Erivan District.			
1st Brigade, 38th Division	8	0	0
1st and 2nd Sunian and Uman Cossacks	0	14	0
Total...	8	14	0
3. Terek District.			
20th Division (Cavalry not specified.)	16	0	5
4. Daghestan District.			
21st Division (Cavalry not specified.)	16	0	6
5. In the interior.			
154th and 155th Regiments..	8	0	0

Note III.

Turkish Forces in Asia.

Commander-in-Chief, Mukhtar Pasha.

	Battns.	Squads.	Guns.	Men.
Batoum, Ardahan, Kars, Bayazid, and advanced detachments	50	18	96	37,000
Between Erzeroum and Kars	30	6	66	20,000
In Kurdistan	12	0	0	8,000
In Syria	27	28	108	22,000
In Yemen	20	0	36	14,000
Total, including local troops ...	139	52	306	101,000
On the Persian frontier	26	12	66	19,000
Total in Asia Minor	165	64	372	120,000

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RUSSIANS.
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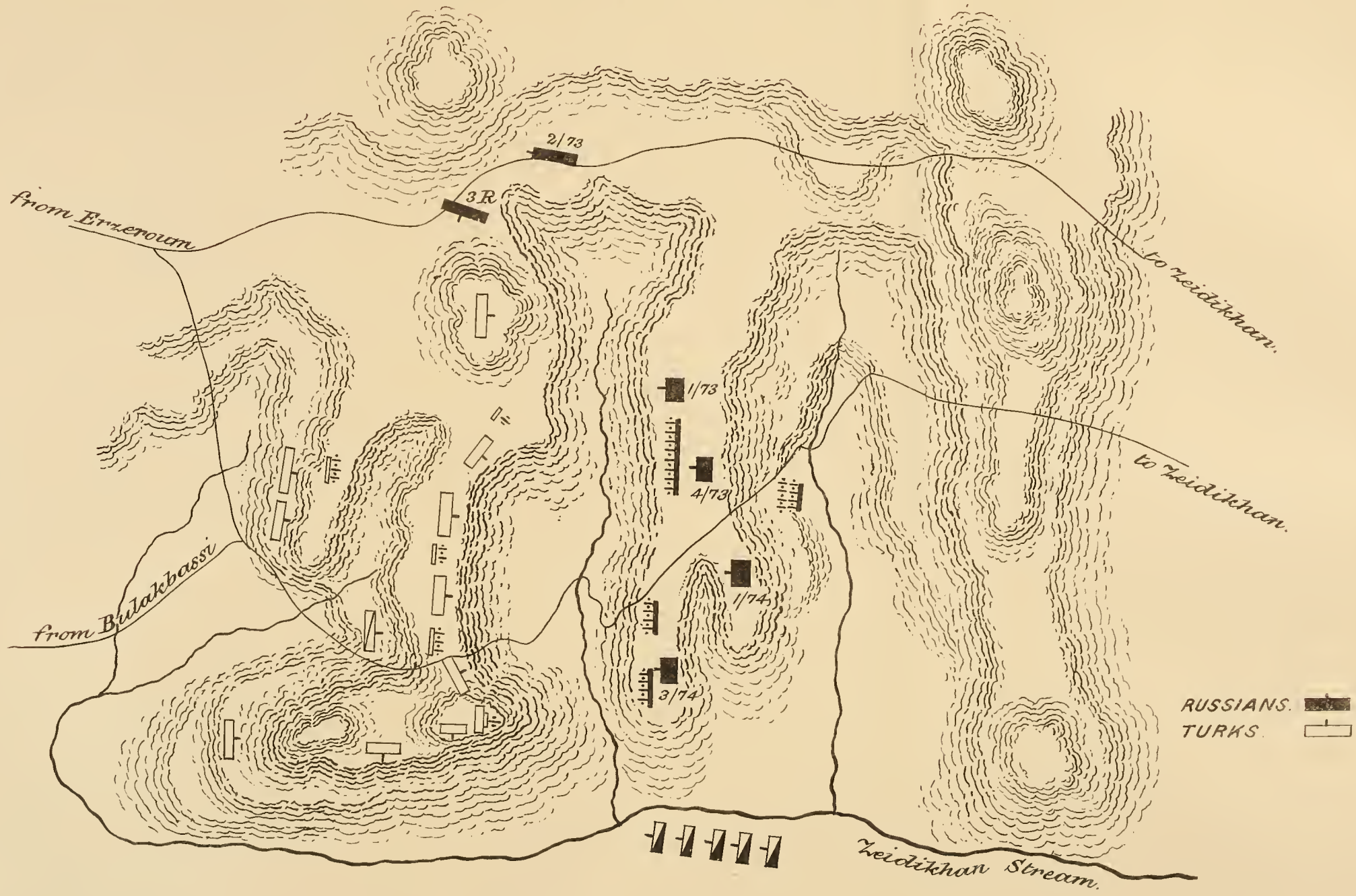
ACTION OF TAGHIR.

JUNE 16th 1877.



ENGLISH MILES.

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CASTLE
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3/13
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3

ENGAGEMENT ON THE ZEWIN PLATEAU.

25 TH JUNE . 1877.

THE NEW AUSTRIAN R.B.L. (15^{cm}) 6-IN. SIEGE GUN OF BRONZE-STEEL.

BY

MAJOR J. F. OWEN, R.A.

The mode of manufacture of the so-called "bronze-steel," as well as the construction of a gun from this metal, have already been described in these "Proceedings" (Vol. IX. No. 4); and full details were given in the same (Vol. X. No. 1) as to the Austrian field guns of pattern 1875 made from this material.

So satisfied are the Austrians with these guns, that they have for some time past been experimenting with a 6-in. B.L. gun, throwing a shot of 85 lbs. with a muzzle velocity of 1476 f.s., and which is constructed also of bronze-steel, as described further on.

In Germany, also, experiments have been lately carried out with steel-bronze guns, in the Arsenal at Spandau, and it is not improbable that even larger guns than that treated of here may be made, having steel-bronze barrels strengthened by rings of the same material secured by shrinkage.

In the "Revue d'Artillerie" for January and June of the current year we find a full account of the experiments which have led to the final adoption of the (15^{cm}) 6-in. bronze-steel gun in Austria. This account is also interesting as showing the progress made abroad in artillery, and as proving that investigations of the description given, when carefully conducted, lead to satisfactory results.

So long ago as 1864, experiments were commenced in Austria in connection with the construction of a cast-iron B.L. (15^{cm}) 6-in. gun, to replace the B.L. gun of this calibre (of pattern 1861).

In order to increase the power of the piece sufficiently to enable it to pierce thin armour-plates, the chamber was enlarged, the size of powder-grain increased, and the charge raised from 4·73 lbs. to

12·94 lbs. By these improvements the muzzle velocity was increased by 263 f.s.

This addition to the charge, however, gave a pressure upon the base of the projectile, on leaving the bore, of about 3·5 tons, which was thought to be too high. A new gun of cast-iron, 10 calibres longer, was therefore made, being a B.L. gun with the Krupp breech-block and Broadwell ring. In June and July, 1867, a muzzle velocity of 1411 f.s. was obtained from this gun, the shell weighing 73¼ lbs., and the charge of powder (pebble, 0·4 to 0·6 in. in diameter) 16·2 lbs. At a distance of 415 yds. its projectiles could penetrate plates of about 5·2 ins. The errors in range and direction were, however, considerable, being due apparently to the effect of the high velocity upon the lead coating, which was much torn, overriding the grooves.

In 1868 experiments were made in Prussia with a steel 15^{cm} B.L. gun (made out of a solid block and not ringed) furnished with the double wedge B.L. apparatus of Kreiner. Principal data as below:—

Weight of gun.	Calibre.	Total length (about).	Length of bore (about.)	Twist.	Powder charge.	Weight of chilled iron shell.	M.V.
cwt.	ins.	ins.	ins.		lbs.	lbs.	f.s.
60	6·0	108	90	1 in 63	15·4	76	1345

The results were good, the gun penetrating, with the chilled iron "Grüson" shell, plates of steel of 6·98 ins. thickness at a distance of 164 yds. The accuracy of the piece was, however, insufficient, and the gun considered too weak for the charges used.

It was determined, therefore, to increase the weight of the gun, to strengthen it with rings, to lengthen the rifled portion from 14 to 18 calibres, and to furnish it with a Krupp cylindro-prismatic B.L. block with Broadwell ring.

Messrs. Krupp were charged with the carrying out of these improvements, both for naval, garrison, and siege guns; but as the accuracy of fire still proved insufficient, the Prussian authorities decided upon another pattern with a sharper twist.

43 of these latter guns were ordered from Krupp by the Austrian Marine, and in 1872 one of them was tried at Pola. The data as to these guns will be found at page opposite.

Meanwhile, experiments were continued in Austria with the long (15^{cm}) 6-in. cast-iron gun, and were completed early in 1873, showing, according to the Report of the Committee—

1st. That the accuracy of the cast-iron long 15^{cm} gun was satisfactory, and much superior to that of the 15^{cm} gun of model 1861.

2nd. That an envelope of hard lead offered no advantages.

3rd. That the twist adopted suited very well for muzzle velocities of from 1493 f.s. to 1575 f.s.

4th. That the copper rings employed weakened the projectile and injuriously affected the accuracy of fire.

The Artillery Committee then proposed to adopt this long 15^{cm} ringed cast-iron gun for both garrison and siege service; but it was considered necessary to obtain not only sufficient accuracy of fire up to a range of (7500^{m}) 8202 yds., but also to pierce tolerably thick plates at a distance of (900^{m}) 984 yds., and lastly to diminish the weight of the gun considerably.

Between March and September, 1874, experiments were carried on with a steel (15^{cm}) 6-in. Krupp ringed gun, which was identical with that which had given such good experimental results in Prussia in 1873. (*Vide* table below).

NOTE.—Throughout this paper the figures in brackets represent the metrical measures and weights.

No. of rounds.	Elevation.	Mean time of flight.	Mean range.	Mean error in	
				Range.	Direction.
	°	secs.	mètres or yds.	mètres or yds.	mètres or yds.
10	40	43·3	(8813) 9638	(70) 76·5	(13·2) 14·4
20	33	37·3	(8465) 9257	(42) 45·9	(17·5) 19·1
24	23·6	28·2	(7434) 8130	(53) 57·9	(7·7) 8·4
18	16·2	20·3	(5578) 6100	(27) 29·5	(5·6) 6·1
15	10·4	13·8	(4199) 4593	(24) 26·2	(3·6) 3·9
15	6·5	10·0	(3214) 3515	(9) 9·8	(2·3) 2·5

The principal data as to this ringed gun are as below, viz. :—

Weight of gun.	Total length.	Approximate length of bore.		Grooves.			Twist.	Charge.	Weight of projectile.	M.V.
				No.	Depth of	Width of				
cwt.	ins.	ins.	cals.		in.	in.		lbs.	lbs.	f.s.
58·6	141·6	102	19	36	0·06	0·37	U.1 in 54	13·64	61·6	1592

A single cylindro-prismatic breech-block with Broadwell ring was used with it.

Three different natures of projectiles were tried :—

(1). Common shells with rings of copper or an envelope of zinc and tin.

(2) Battering projectiles of steel and of chilled iron with rings of zinc.

(3) Similar projectiles with rings of brass.

At (500^{m}) 547 yds. the battering projectiles pierced an iron plate (15^{mm}) 5·9 ins. thick and inclined at an angle of 14½°.

Experiments for range and accuracy at (1500^{m}) 1640 and (2000^{m}) 2187 yds. gave bad results, apparently due to the mode of rotation, and accordingly, in September, 1874, further practice was carried out

with projectiles furnished with four copper rings instead of those coated with an alloy of zinc and tin. The results are given below :—

No. of rounds.	Weight of shell.	Powder charge.	M.V.	Angles. Departure.	Angles. Descent.	Mean range.	Mean errors. In range.	Mean errors. In direction.	Mean errors. In height.
	lbs.	lbs.	f.s.	° ′	° ′	yds.	yds.	yds.	yds.
10	(28·884) 63·5, with copper rings.	(6·2) 13·64	(477) 1565	2 11	3 0	(1525) 1667	(16·5) 11·5	(0·56) 0·612	(0·54) 0·59
10		(6·0) 13·2	(469) 1539	2 16	3 2	(1545) 1689	(9·3) 10·2	(0·56) 0·612	(0·50) 0·55
10		(5·8) 12·76	(463) 1519	2 21	3 8	(1545) 1689	(8·1) 8·8	(0·58) 0·634	(0·45) 0·49
10	(28·444) 62·6, with covering of tin & zinc	(6·2) 13·64	(463) 1519	2 14	3 0	(1523) 1665	(18·9) 20·5	(0·48) 0·525	(0·98) 1.072

The new projectiles gave rather more penetration against iron plates, and two chilled projectiles went completely through the target (5·9 ins. thick) at a distance of (500^{m}) 547 yds.

Such was the state of the question at the end of 1874, when the military Committee were compelled to abandon it for a time, in order to devote themselves to the new bronze-steel field guns of model 1875.

The excellent results given by these guns induced the Committee to request General Uchatius to ascertain whether larger guns could not be made of this metal, and in particular a (15^{cm}) 6-in. gun of similar dimensions to that of steel tried in 1874.

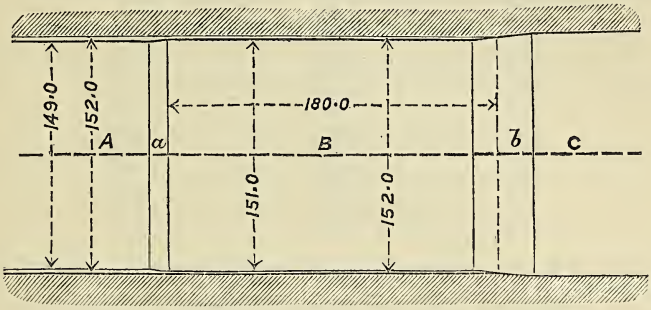
General Uchatius having tested a tube of (15^{cm}) 6 ins. calibre with similar charges to those it was proposed to use, and having found the limit of elasticity sufficient, two bronze-steel guns of this calibre were made—one with a uniform twist (No. 1 gun), and the other with increasing twist (No. 2 gun); the rifling, as well as the interior dimensions, being fixed upon by the Committee.

In exterior dimensions and in construction the guns were identical, and in the latter point they resembled the field guns of 1875, except that in front of the breech-block slot and for the length of the powder-chamber they were strengthened by a strong ring of bronze-steel.

As to the interior, however, they differed in length of rifling, as will be seen by the table below :—

Nature of gun.	Weight.	Total length.	Calibre.	Length of bore, about.		Rifling. Length.	Rifling. Twist.	Powder chamber, about. Length.	Powder chamber, about. Calibre.	Powder chamber, about. Capacity.	Grooves. Number.	Grooves. Depth.	Grooves. Breadth.	Preponderance.
	cwt.	ft.	ins.	ins.	cals.							ins.	ins.	lbs.
No. 1 gun	(3,235) 63·7	(3,600) 11·81	(149) 5·864	125	21½	(2535) 99·86	U.1 in 45	19·5	6·30	615	36	0·06	0·37	205
No. 2 gun	63·7	11·81	5·864	125	21½	(2715) 106·9	I. 0 to 1 in 45	19·5	6·30	615	36	0·06	0·37	205

In No. 2 gun the rifled portion is 1·2 calibres longer than in No. 1, as the grooves are extended for that length into the shot-chamber, starting from the cone where this chamber—which is (2^{mm}) 0·078 ins. larger than the bore—joins the powder-chamber of still larger diameter. (*Vide* figure below.)



The object of this extension of the rifling is to centre the projectile as soon as it begins to move.

In both guns the vent is of copper in two pieces, and strikes the powder-chamber at right angles at (75^{mm}) 2·95 ins. from the face of the breech-block.

The B.L. apparatus is exactly similar to that of the field guns of 1875,* the breech-block being of bronze-steel and the obturator of copper. The plate at the end of the paper shows approximately the gun in question; though, as many of the required data are wanting, its dimensions are not in all cases correct.

The projectiles for the gun with uniform twist were furnished with four copper rings—two towards the front and two towards the rear; while the shell for the gun with increasing twist had only two rings—one towards the front to ensure centring, and one towards the rear for rotating the projectile.

The normal charge was to be that which would give a muzzle velocity of (450^{ms}) 1476 f.s. to a shell of 85·5 lbs., with a maximum pressure of (2000^{k}) 13·1 tons per square inch in the powder-chamber.

Experiments were begun in 1877, several natures of powder being tried:—

	Size of grains.	Density.
No. 1	(6 to 10^{mm}) (0·25 to 0·39)	1·663
No. 2	(6^{mm}) (0·25)	1·721 to 1·772
No. 3	(12 to 15^{mm}) (0·47 to 0·60)	1·671, 1·686, 1·702

That adopted was No. 3, of density 1·686.

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* *Vide* "Proceedings, R.A. Institution," Vol. X., No. 1, p. 5.

With No. 1 gun this powder gave the following velocities and maximum pressures :—

Charge. lbs.	V.* f.s.	Max. pressure, tons per sq. in.
(6)	(371·0)	(1106)
13·2	1217·2	7·25
($6\frac{1}{2}$)	(389·2)	(1324)
14·3	1276·2	8·70
($6\frac{3}{4}$)	(399·6)	(1415)
14·8	1309·1	9·30
(7)	(409·3)	(1507)
15·4	1343·0	9·90
($7\frac{1}{4}$)	(418·6)	(1658)
15·9	1372·4	10·85
($7\frac{1}{2}$)	(427·3)	(1682)
16·5	1400·9	11·05
($7\frac{3}{4}$)	(436·8)	(1780)
17·0	1432·4	11·70
(8)	(444·3)	(1887)
17·6	1457·0	12·40

With No. 2 gun a charge of (8^k) 17·6 lbs. of this powder gave a velocity of (445·4) 1460 f.s.,* with a maximum pressure of (1997) 13·1 tons per square inch.

A normal charge of 17·6 lbs. of this powder was consequently fixed upon.

Further experiments were now carried out, in order to determine the respective range and accuracy of the two guns, and to decide upon the means of rotation to be adopted for the projectiles. These latter were 2·8 calibres in length, and had been found to give greater range and penetration than those of 2·5 calibres.

The shell for No. 1 gun were furnished (as already mentioned) with four copper rings, as in the case of those of the field guns of 1875 ;† those for No. 2 gun were provided with two copper rings (20^{mm}) 0·787 in. in breadth, and of the shape shown in the diagrams below.

Fig. 2 shows the forward ring, the exterior diameter of which is such that it will penetrate ($0·1^{mm}$) 0·39 in. into the grooves of the gun, but not into those of the shot-chamber. The rear or rotating ring (Fig. 1) acts, however, in the shot-chamber; its exterior diameter being greater by ($0·1^{mm}$) 0·39 in. than that of the gun, measured from the bottom of the grooves.

Fig. 1.

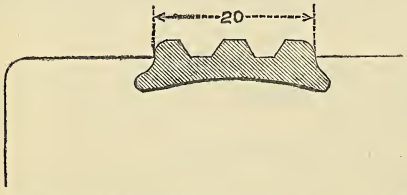


Fig. 2.

The table below gives a comparison of the results of the first trials of the two guns with those of the Krupp 15^{cm} steel gun, tried in 1874, and the long Austrian cast-iron ringed 15^{cm} gun already mentioned.

* At about 50 yds. from the muzzle.

† *Vide* "Proceedings, R.A. Institution," Vol. X., No. 1, p. 10.

It will be seen that the two bronze-steel guns give about the same ballistic results.

Nature of gun.	Calibre.	Weight.			Relation of weights of shell and charge.	Velocity at muzzle	Energy at muzzle.	
		Gun.	Shell.	Powd. charge			per lb. of charge.	Per in. of shot's circumf.
	ins.	cwt.	lbs.	lbs.				
Bronze steel (15cm) 6in.gn. No.1uniform twist	(149) 5·87	(3225) 63·2	(38·8) 85·5	(8·0) 17·6	$\frac{1}{4·8} = 0·206$ ...	1469	1156	69
Bronze steel (15cm) 6in.gn. " 2 increasing "	(144) 5·87	(3235) 63·7	(38·8) 85·5	(8·0) 17·6	$\frac{1}{4·8} = 0·206$ ...	1476	1290	70
Krupp (15cm) 6-in. steel gun, tried in 1874	(149·1) 5·9	(2983) 58·7	(32·32) 71·1	(6·5) 14·3	$\frac{1}{5} = 0·201$ ...	1536	1085	58
Long Austrian (15cm) 6-in. marine gun (cast-iron, strengthened)	(149·1) 5·9	(4060) 78·7	(35·5) 78·1	(8·0) 17·6	$\frac{1}{4·5} = 0·225$ ...	1531	1270	68

The 6-in. guns of bronze-steel thus gave a muzzle velocity of about 1476 f.s., and had at (50m) 164 ft. from the muzzle an energy per inch of shot's circumference, and consequently a penetrative power against plates, greater than the steel 6-in. gun of Krupp, and about the same as the long marine 6-in. gun, although the latter had at that range a somewhat greater remaining velocity.

Judging from former experiments, this amount of energy would be sufficient to perforate wrought-iron plates (16cm) 6·3 ins. in thickness, together with their wood backing, at some distance.

It was decided, therefore, that the guns in question could be used with advantage as auxiliary pieces in coast batteries, for firing against armour-clad ships.

Accuracy of Fire.

The practice to determine the above, carried out in series of 20 rounds from each gun, at ranges of (1000m) 1094 yds., (2000m) 2187 yds., and (3000m) 3281 yds., showed that both guns gave very good shooting, and that there was apparently but little difference between them. To obtain a more complete comparison, three series of 20 rounds were fired from each gun at a range of (2000m) 2187 yds.

Further, in order to test the effect of the wear of the bore upon the accuracy of fire, the total number of rounds fired from each gun was brought up to 300, by firing at the same range comparative series of 25 rounds each.

Notwithstanding the comparatively large number of rounds fired, no diminution of accuracy of fire could be observed.

Lastly, in order to determine the relative superiority of the two guns, two series of 20 rounds were fired with projectiles the copper rings or belts of which had been turned down to (0·3mm) 0·012 in. below their proper size. This gave a condition representing a considerable wear of the bore, and enabled one at the same time to fix upon the limits of error to be allowed in manufacture of the projectiles.

The following table gives the results obtained during these experiments, together with the comparative results given by the steel ringed

6-in. gun of Krupp and the long Austrian B.L. cast-iron (strengthened) 6-in. gun :—

Nature of gun.	No. of rounds. Fired previously.	During the series.	From which the means were taken.	Angle of elevation.	Mean range.	Mean errors. Height.	Range.	Direction.	Mean of errors in height.	No. of shots per 100 which would strike a target (1m)3·28ft. high
				° ′ ″		yds.	yds.	yds.		
Steel-bronze B.L. 6-in. gun, No. 1. Twist, uniform. Shell, 2·8 cals. long, with four copper rings; weight, 85·5 lbs. Charge, 17·6 "	176	10	9	0 17 44	(635·4)	(0·08)	(5·4)	(0·13)	(0·08)	98·6
					696	0·087	5·9	0·142	0·087	
	59	15	13	1 35 58	(1053·7)	(0·17)	(4·2)	(0·18)	(0·19)	92·1
					1153	0·186	4·6	0·197	0·208	
	166	10	10	1 34 44	(1064·0)	(0·20)	(6·1)	(0·41)		
					1164	0·219	6·67	0·448		
	39	20	16	3 31 16	(2003·9)	(0·73)	(8·3)	(0·98)		
					2191	0·798	9·07	1·07		
	96	25	20	3 21 13	(2017·8)	(1·02)	(14·0)	(0·64)		
					2216	1·11	15·3	0·70		
	121	25	25	3 26 31	(2041·3)	(0·64)	(9·6)	(0·84)		
					2242	0·70	9·84	0·919	(0·81)	38·7
	146	20	20	3 25 14	(2042·6)	(0·76)	(11·3)	(6·81)	0·88	
					2243	0·941	12·3	0·875		
	207	23	21	3 40 57	(2016·4)	(1·66)	(8·4)	(1·21)		
					2215	1·810	9·18	1·32		
	250	25	20	3 47 28	(2014·7)	(1·19)	(14·1)	(0·66)		
					2212	1·22	15·4	0·722		
	275	25	25	3 45 25	(2029·0)	(0·83)	(10·6)	(0·67)		
					2219	0·908	11·5	0·733		
	74	22	19	5 54 29	(3010·6)	(1·61)	(12·1)	(1·86)		
					3292	1·84	13·2	2·01	(1·63)	19·5
	230	20	19	6 8 44	(2916·7)	(1·65)	(12·2)	(2·11)	1·78	
					3172	1·86	13·4	2·39		
Fired with projectiles of which rings were (0·3mm) 0·012 in. under size.	300	20	19	3 46 7	(2022·2)	(0·72)	(7·1)	(0·17)	—	—
					2211	0·787	9·9	0·185		
	320	20	19	3 44 53	(2031·7)	(0·78)	(10·1)	(0·55)	—	—
					2222	0·853	11·1	0·602		
Steel-bronze B.L. 6-in. gun, No. 2. Twist, increasing. Shell, 2·8 cals. long, with two copper rings; weight, 85·5 lbs. Charge, 17·6 "	168	10	9	0 47 58	(646·1)	(0·14)	(9·6)	(0·16)	(0·14)	84·5
					706	0·153	10·4	0·175	0·153	
	51	15	9	1 33 47	(1062·7)	(0·12)	(3·7)	(6·27)		
					1162	0·131	4·1	0·295	(0·18)	75·9
	158	10	10	1 34 1	(1060·2)	(0·23)	(7·4)	(0·37)	0·197	
					1161	0·252	8·1	0·405		
	31	20	18	3 27 17	(2034·9)	(0·34)	(5·5)	(0·87)		
					2225	0·372	6·0	1·06		
	88	25	20	3 17 16	(2004·7)	(0·52)	(6·7)	(0·73)		
					2193	0·569	7·3	0·798		
	113	25	22	3 23 58	(2020·3)	(0·50)	(7·1)	(0·52)		
					2209	0·547	7·7	0·569		
	138	20	20	3 23 49	(2034·3)	(0·75)	(11·2)	(0·58)	(0·66)	48·7
					2224	0·82	12·2	0·63	0·722	
	207	23	21	3 33 17	(2037·3)	(0·60)	(7·9)	(1·03)		
					2227	0·65	8·6	1·40		
	250	25	21	3 37 23	(2025·6)	(1·20)	(15·1)	(0·73)		
					2215	1·31	16·5	0·788		
	275	25	25	3 35 45	(2031·5)	(0·64)	(8·4)	(0·86)		
					2222	0·700	9·2	0·941		
	66	22	19	5 49 28	(3010·6)	(1·85)	(13·9)	(1·82)		
					3302	2·42	15·2	2·36	(1·50)	22·2
	230	20	18	6 8 40	(3024·0)	(1·15)	(9·3)	(1·47)	1·64	
					3307	1·25	10·2	1·60		
Fired with copper rings 0·012 in. under size.	300	20	17	3 41 58	(2021·8)	(0·64)	(8·5)	(0·83)	—	—
					2211	0·700	9·3	0·908		
	320	20	17	3 37 1	(2040·5)	(0·75)	(8·9)	(0·71)	—	—
					2231	0·820	9·7	0·776		

(*Continued.*)

Nature of gun.	No. of rounds. Fired previously.	No. of rounds. During the series.	No. of rounds. From which the means were taken.	Angle of elevation.	Mean range.	Mean errors. Height.	Mean errors. Range.	Mean errors. Direction.	Mean of errors in height.	No. of shots per 100 which would strike a target (1m)3·28ft. high
				° ′ ″		yds.	yds.	yds.		
(15cm)6-in.B.L. cast-iron gun, m/61. Lead-coated shells, 2·3 cals; weight, 61·6. Charge (2·15k) 4·73 lbs.	—	—	—	1 23 0	(500) 547	(0·21) 0·23	(7·6) 8·3	(0·19) 0·208	—	62·2
	—	—	—	3 3 0	(1000) 1094	(0·61) 0·667	(10·3) 11·1	(0·46) 0·503	—	27·2
	—	—	—	6 46 0	(2000) 2187	(2·11) 2·30	(15·5) 16·9	(1·22) 1·33	—	15·0
	—	—	—	11 8 0	(3000) 3281	(4·92) 5·36	(20·5) 22·4	(2·28) 2·36	—	6·5
6-in. B.L. steel gun of Krupp. Shell with two copper rings, 2·8 cals. long; weight, (35·5k) 78·1 lbs. Charge (8k) 17·6 lbs.	—	—	—	—	(1000) 1094	(0·35) 0·383	(13·6) 14·8	(0·43) 0·470	—	42·4
	—	—	—	—	(2000) 2187	(0·70) 0·766	(10·6) 11·6	(1·01) 1·10	—	42·4

It will be seen from this table that in accuracy No. 2 gun is superior to No. 1; the number of shots per 100 which would strike a target 3·28 ft. high being considerably greater with the former gun, commencing at (1000m) 1094 yds.

This superiority is very evident at (2000m) 2187 yds. range, at which range each gun fired more than 180 rounds; and taking the mean of these, we see that the number of hits per 100 shots striking such a target are, with No. 1 gun 38·7, and with No. 2 gun 48·7; or rather more than a fourth more hits in favour of the latter.

With the same angle of elevation, No. 2 gun also gives a rather higher range than No. 1, the advantage being (63m) 69 yds. in (3000m) 3281 yds.

On the whole, both guns proved very accurate—very much superior to the (15cm) 6-in., m/61, of which the errors in height at similar ranges are three times as great as those of the new guns. Compared with the 6-in. steel Krupp gun, the results at (2000m) 2187 yds. are about equal, but at (1000m) 1092 yds. they are superior.

As to endurance, the (15cm) 6-in. bronze-steel guns have shown themselves as satisfactory as the field guns of pattern 1875. Notwithstanding considerable erosion of the bore and degradation of the lands, the accuracy of fire was not diminished. In both cases the powder-chamber has remained intact; the erosion commencing at the cone joining this with the shot-chamber. In this cone, and in the shot-chamber itself, this erosion was principally developed; the deepest portion being in the upper surface and having a depth of (3mm) 0·12 in. in No. 1 gun, and of (4mm) 0·16 in. in No. 2 gun.

In No. 2 gun the lower lands in the shot-chamber are almost obliterated in places; so that the employment of the rings does not prevent erosion, as was hoped. The rifled portion of the bore, properly so

called, remained intact in both guns; the edges of the lands at the cone where the shot-chamber joins this portion being merely worn away to a slight degree.

The expansions of the bore in both guns are unimportant, viz.:—

Gun.	Powder-chamber.	Shot-chamber.	Rifled part of bore.
	in.	in.	in.
No. 1	0·005 to 0·007	0·014	0·008 to 0·0047 Rapidly decreasing.
No. 2	"	0·014 in lands. 0·025 in grooves.	

The wear is greater than that experienced with the field guns after the same number of rounds, but such wear is found to occur even with steel tubes. Besides, even in the last series, fired with shell having rings (0·3^{mm}) 0·012-in. below the proper diameter, no diminution of accuracy occurred; so that none need be feared, even should the bore be expanded by (0·3^{mm}) 0·012 in., or if the rings should be that amount below their proper size.

Finally, the state of the bore of both guns at the end of the experiments was such as to lead to the conclusion that these (15^{cm}) 6-in. bronze-steel guns would have quite sufficient endurance.

The breech-loading apparatus acted perfectly throughout the whole of the experiments: one obturator (obturating ring and plate) stood 141 rounds in No. 1 gun, and another stood 280 rounds in No. 2 gun.

On the whole, the Committee arrived at the following conclusions:—*

1. That bronze-steel answers well for the construction of (15^{cm}) 6-in. guns destined to fire heavy charges.

2. That the penetrating power of the two guns as against iron plates is about the same, and that the energy per inch of shot's circumference is superior to that of the Krupp (15^{cm}) 6-in. ringed gun.

3. With regard to accuracy of fire, both guns fulfilled the conditions required. Gun No. 2 with increasing twist seems superior to No. 1 with a uniform twist. In the former, owing to the rifling being carried into the shot-chamber, the projectile is better centred. The extra expense of this development of the rifling is only about £1 13s. per gun—the total cost of the piece being £320—and would probably be more than compensated for by the increased economy in projectiles required to effect a given result.

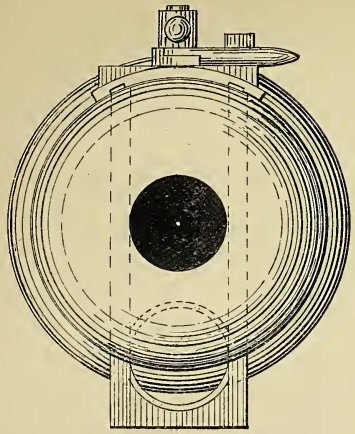
As observed in previous papers, it may have been judicious on the part of the Austrian artillery authorities to adopt this material for the time being for such pieces on economical grounds, there being numbers of old S.B. bronze guns in hand, and also because the manufacture could be at once carried out in their Arsenal without delay. We cannot, however, suppose that in the long run this material will be able to hold its own against the stronger metal steel, in the production and manufacture of which very great progress has lately been made, as fully exemplified in the Exhibition in Paris of this year.

* In consequence of this report it is understood that about 15 of these pieces have already been manufactured for the Austrian service, but no information can be given as to their behaviour under service conditions.

NEW AUSTRIAN 6 INCH (85 PR.) B.L. SIEGE GUN OF STEEL BRONZE.

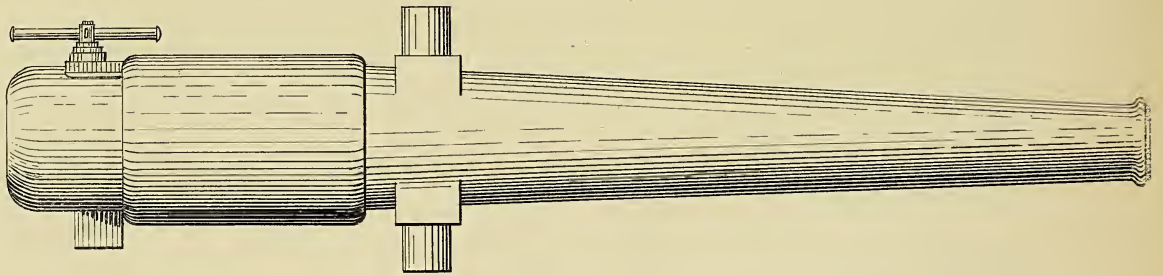
Scale ½ inch = 1 Foot.

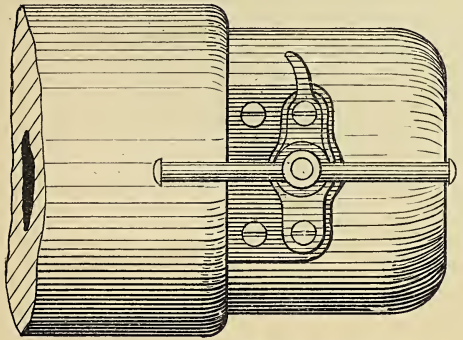
END VIEW LOOKING ON BREECH.



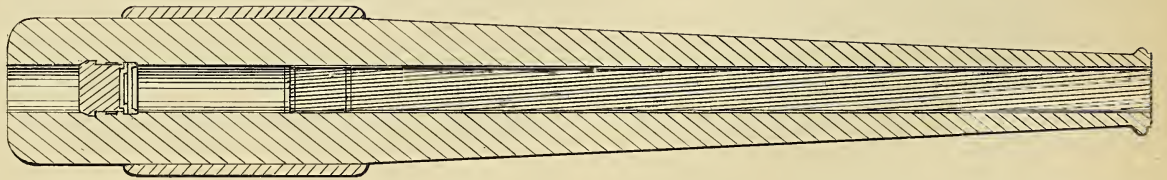
Scale 1 inch = 1 Foot.

WEIGHT 63·7 CWT.





SIDE VIEW OF BREECH.



N.B. Proportions only approximately correct.

PRINCIPLES OF GUNNERY.

RIFLED ORDNANCE.

BY

CAPTAIN J. SLADEN, R.A.

PROFESSOR OF ARTILLERY, R.M. ACADEMY, WOOLWICH.

(*Continued from p. 368.*)

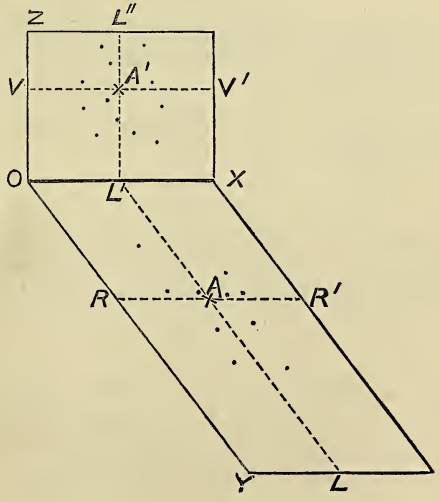
CHAPTER VIII.

Accuracy and Probability of Fire.

Mean Range.—Mean Lateral Deviation.—Mean Vertical Deviation.—Mean Error in Range, or Mean Longitudinal Error.—Mean Lateral Error.—Mean Vertical Error.—Mean Absolute Error.—Method of Estimating the Accuracy of Small-Arms and Ordnance.—Example of Testing Guns for Range and Accuracy.—Zones of Fire.—Probable Rectangles.—Table of Probability Factors.—The Probability of Hitting a Target of given Dimensions.—Causes which Affect Accuracy of Fire.—Variations in Muzzle Velocity.—Unsteadiness of the Projectile as it leaves the Bore and during Flight.—Wind.—Personal Error in Laying.—Inclination of the Trunnions to the Horizon.—Unsteadiness of Gun, Carriage, and Platform on Firing.

In order to judge of the relative accuracy of fire of different guns, it is necessary to fire a large number of rounds from each gun, and compare the results. It is usually done by firing at a horizontal target, and if possible at a vertical target.

The mean range is obtained by dividing the sum of the ranges of Mean range.



each shot by the number of rounds fired. Thus, RR' represents the line of mean range.

Mean lateral deviation.

The mean lateral deviation is obtained by dividing the algebraical sum of the lateral deviations of each shot by the number of rounds fired. Thus, LL' represents the line of mean lateral deviation.

Mean vertical deviation.

The mean vertical deviation is obtained by dividing the sum of the vertical deviations of each shot from the horizontal line OX by the number of rounds fired. Thus, VV' represents the line of mean vertical deviation.

The intersection of the lines RR' and LL' gives A, the point of mean impact on the horizontal target; and the intersection of the lines $L'L''$ and VV' gives A', the point of mean impact on the vertical target.

Mean error in range, or mean longitudinal error.

The mean error in range, or the mean longitudinal error, is obtained by taking the numerical sum of the differences between the range of each shot and the mean range, and dividing by the number of rounds fired.

Mean lateral error.

The mean lateral error is obtained by taking the numerical sum of the differences between the lateral deviation of each shot and the mean lateral deviation, and dividing by the number of rounds fired.

Mean vertical error.

The mean vertical error is obtained by taking the numerical sum of the differences between the vertical deviation of each shot and the mean vertical deviation, and dividing by the number of rounds fired.

Mean absolute error.

The mean absolute error is obtained by taking the sum of the radial distances of each shot from the point of mean impact, and dividing by the number of rounds fired.

The mean absolute error may be estimated both on the horizontal and on the vertical target.

Method of estimating the accuracy of small-arms and ordnance.

In order to estimate the relative accuracy of small-arms, the *mean absolute error* is taken on a vertical target. To estimate the relative accuracy of ordnance, the *mean longitudinal, lateral,* and *vertical errors* are observed.

Example of testing guns for range and accuracy.

As an example of testing guns for range and accuracy, a direct comparison of the shooting of a long 40-pr. and a short 40-pr. M.L. gun is given in detail. The length of bore of the long 40-pr. was 22 calibres; that of the short 40-pr. was 18 calibres.

Date, and wind.	Rounds.	Gun.	Elevation.	Mean time of flight.	Ranges. Min.	Max.	Mean.	Mean error in range.	Mean lateral deviation.	Mean lateral error.
			°	secs.	yds.	yds.	yds.	yds.	yds.	yds.
30. 1. 74. → 2 to 4	10	Short	3	4·32	1513	1581	1547	17·2	3·08 R.	0·42
"	10*	Long	3	4·44†	1558	1698	1637	30·2	4·20 "	1·38
" → 0 to 1	10	Short	5	6·64	2248	2315	2278	15·8	8·24 "	1·33
"	10	Long	5	6·81	2357	2413	2387	17·9	9·02 "	1·23
5. 2. 74. ← ↖ ↗ ↑ 1 to 2	10	Short	10	12·24‡	3689	3868	3736	41·4	9·22 "	3·06
"	10	Long	10	12·47§	3794	3973	3898	43·6	12·10 "	3·44

* Mean of 9 rounds; 1 omitted as being irregular.
† " 8 " 1 not observed; 1 omitted as being irregular.
‡ " 8 rounds; 2 not observed.
§ " 9 " 1 "

To show how the mean time of flight, mean range, mean error in range, mean lateral deviation, and mean lateral error are obtained, the result of each of 10 rounds fired from the long 40-pr. gun at 5° elevation is given in detail.

No. of rounds.	Elevation.	Charge.	Weight of projectile.	Time of flight.	Range. 1st graze and mean.	Range. Difference of each range from mean.	Lateral deviation. Left.	Lateral deviation. Right.	Lateral error. Left.	Lateral error. Right.
	°	lbs.	lbs.	secs.	yds.	yds.	yds.	yds.	yds.	yds.
1	5	7	38½	6·8	2396	9	—	9	—	·02
2	"	"	"	6·8	2386	1	—	8·4	—	·62
3	"	"	"	6·8	2375	12	—	10	—	·98
4	"	"	"	6·8	2357	30	—	7	—	2·02
5	"	"	"	6·9	2410	23	—	7·2	—	1·82
6	"	"	"	6·7	2361	26	—	10·2	—	1·18
7	"	"	"	6·8	2413	26	—	9	—	·02
8	"	"	"	6·8	2403	16	—	7·4	—	1·62
9	"	"	"	6·9	2401	14	—	9	—	·02
10	"	"	"	6·8	2365	22	—	13	—	3·98
			10	68·1	23867	179	—	90·2	—	12·28
				6·81	2387	17·9	—	9·02	—	1·23

The mean time of flight is 6·81 secs.
Mean range ..... 2387 yds.
" error in range ..... 17·9 "
" lateral deviation ... 9·02 " right
" " error ..... 1·23 "

Probability of Hitting.

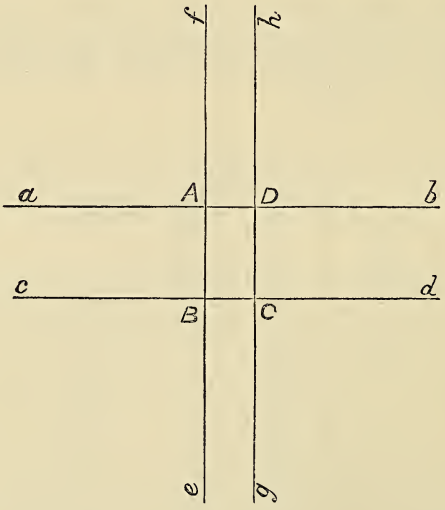
Zones of fire.

By the Theory of Probabilities it may be shown that the dimensions of the zones of fire in which 50 per cent. of the shot would probably strike may be obtained by multiplying the mean errors by the factor 1·69.

If the mean error in range be denoted by R,
" " lateral error " L,
" " vertical error " V,

the depth of the zone containing 50 per cent. of the shot is $1{\cdot}69R$,
" breadth " " " " $1{\cdot}69L$,
" height " " " " $1{\cdot}69V$.

These zones of fire are quite independent of one another, and are bounded by two indefinite parallel straight lines, distant from one another by the amount given above.



Thus, firing at a horizontal target, if R is the mean error in range, then the length included between the two indefinite parallel straight lines ab and cd, distant $1{\cdot}69R$ from one another, represents the depth of the zone containing 50 per cent. of the shot fired; and if L is the mean lateral error, then the length included between the two indefinite parallel straight lines ef and gh, distant $1{\cdot}69L$ from one another, represents the breadth of the zone containing 50 per cent. of the shot fired.

The rectangle, *ABCD*, enclosed by the intersection of these zones, represents the area in which 50 per cent. of 50 per cent.—*i.e.*, 25 per cent.—of the shot will probably strike. A vertical rectangle may also be obtained in the same way, if the mean vertical and lateral errors are known. This is the method of calculating the probable rectangle usually adopted on the Continent. Probable rectangles.

A comparison of rectangles made out from the results obtained by firing different guns, affords a good criterion of their respective accuracy of fire.

These rectangles are called *probable rectangles.*

The dimensions of the British probable rectangle hitherto adopted are 1·56 times larger than those of the former, but it is proposed in future to adopt the probable rectangle in use on the Continent.

The British probable rectangle represents the area in which 50 per cent. of the shot will probably strike—*i.e.*, twice the probable number of shots contained in the Continental rectangle.

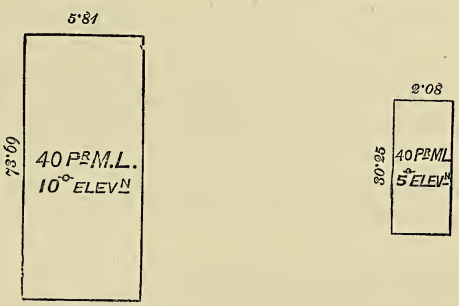
The sides of the British 50 per cent. probable rectangle may be directly obtained by multiplying the mean errors by $1{\cdot}69 \times 1{\cdot}56 = 2{\cdot}64$.

As the Continental method is simpler for calculation, an example of its employment will be given in the case of the 40-pr. M.L. (long) gun at 5° elevation. (*Vide* p. 427.)

The length of the 25 per cent. probable rectangle = 17·9 × 1·69 = 30·25 yds.
" breadth " " " " = 1·23 × 1·69 = 2·08 "

And at 10° elevation :—

The length of the 25 per cent. probable rectangle = 43·6 × 1·69 = 73·69 yds.
" breadth " " " " = 3·44 × 1·69 = 5·81 "



These rectangles represent the area (horizontal) in which 25 per cent. of the shot will probably strike.

When the mean errors of a gun at a given range are known, the probability of hitting a target of given dimensions can be calculated by means of a Table of Probability Factors.

The following table gives factors by which the dimensions of the zones containing 50 per cent. of the shot must be multiplied in order to determine the per-centage of hits on a target of given dimensions :— Table of Probability Factors.

Table of Probability Factors.

Per cent.	Factor	Per cent.	Factor	Per cent.	Factor	Per cent.	Factor	Per cent.	Factor
1	·02	21	·40	41	·80	61	1·27	81	1·94
2	·04	22	·41	42	·82	62	1·30	82	1·98
3	·06	23	·43	43	·84	63	1·33	83	2·03
4	·07	24	·45	44	·86	64	1·36	84	2·08
5	·09	25	·47	45	·89	65	1·39	85	2·13
6	·11	26	·49	46	·91	66	1·42	86	2·18
7	·13	27	·51	47	·93	67	1·45	87	2·24
8	·15	28	·53	48	·95	68	1·48	88	2·30
9	·17	29	·55	49	·98	69	1·51	89	2·37
10	·18	30	·57	50	1·00	70	1·54	90	2·44
11	·20	31	·59	51	1·02	71	1·57	91	2·52
12	·22	32	·61	52	1·04	72	1·60	92	2·60
13	·24	33	·63	53	1·07	73	1·64	93	2·69
14	·26	34	·65	54	1·09	74	1·67	94	2·78
15	·28	35	·67	55	1·12	75	1·71	95	2·91
16	·30	36	·70	56	1·14	76	1·74	96	3·04
17	·32	37	·72	57	1·17	77	1·78	97	3·22
18	·34	38	·74	58	1·19	78	1·82	98	3·45
19	·36	39	·76	59	1·22	79	1·86	99	3·82
20	·38	40	·78	60	1·25	80	1·90	100	∞

The probability of hitting a target of given dimensions.

Take for example the case of the 40-pr. M.L.R. gun at 5° elevation. The depth of the zone containing 50 per cent. of the shot is 30·25 yds.; the breadth of the zone containing 50 per cent. of the shot is 2·08 yds.

What per-centage of shot from the 40-pr. M.L.R. at 5° elevation at a mean range of 2387 yds. will probably hit a horizontal target 40 yds. long by 4 yds. broad?

The probability factor for length is obtained by dividing the length of the target by the depth of the zone containing 50 per cent. of the shot. Thus,

$$\text{probability factor for length} = \frac{40}{30{\cdot}25} = 1{\cdot}32.$$

By reference to the Table of Probability Factors it will be seen that 1·32 corresponds to 62·7 per cent., which shows that 62·7 per cent. of the shot will probably fall into a zone 40 yds. in depth and of indefinite breadth.

The probability factor for breadth is obtained by dividing the breadth of the target by the breadth of the zone containing 50 per cent. of the shot. Thus,

$$\text{probability factor for breadth} = \frac{4}{2{\cdot}08} = 1{\cdot}92.$$

By reference to the Table of Probability Factors, it will be seen that 1·92 corresponds to 80·5 per cent., which shows that 80·5 per cent. of the shot will probably fall into a zone 4 yds. in breadth and of indefinite length.

The product of the per-centages thus found will give the per-centage of hits on the target. Thus, probable number of hits = 62·7 per cent. of 80·5 per cent. = 50·5 per cent.

The same method applies for determining the per-centage of hits on a vertical target, if the mean vertical and lateral errors of the gun are known.

ERRORS OF FIRE ARE DUE PRINCIPALLY TO

Causes which affect accuracy of fire.

(1) Variations in muzzle velocity.
(2) Unsteadiness of the projectile as it leaves the bore, and during flight.
(3) Wind.
(4) Personal error in laying.
(5) Inclination of the trunnions to the horizon.
(6) Unsteadiness of gun, carriage, and platform on firing.

Variations in muzzle velocity.

It is important, in order to obtain great accuracy of fire, to have the muzzle velocity as uniform as possible. Variations in muzzle velocity result from want of uniformity in the explosion of the charge, which may result from the quality of the powder, the amount of moisture in the powder, or the variation in the cubic space occupied by the charge, and the shape of the cartridge. For instance, the degree of hardness in ramming home will cause a variation in muzzle velocity in those guns where there is not a special provision to stop the projectile at a fixed distance. Another cause of variations in muzzle velocity is the small difference in the weight of projectiles and charges.

The temperature of the gun affects the muzzle velocity. Generally, the first round is short, owing to the muzzle velocity being below the average in a cool gun.

Unsteadiness of the projectile as it leaves the bore and during flight.

The unsteadiness of a projectile as it leaves the bore is the most important source of errors in fire. It may result from accidental causes—such as the shearing of the studs, the breaking up of the gas-check, or from the contact of the body of the projectile with the lands of the bore. In B.L. guns it may result from the lead coat stripping; but in M.L. guns it more commonly arises from non-centring, or insufficient velocity of rotation, or eccentricity of the projectile, and in some cases on the system of rifling employed. This unsteadiness causes greater loss of velocity during flight, since the projectile then presents a greater surface for resistance than when the axis is steady, hence the range is diminished; also, since the drift is allowed for under normal conditions by the inclination of the tangent sights to the left, any unsteadiness of the projectile at the muzzle or during flight will cause a variation in the actual drift, which results in both lateral and vertical error.

Wind.

The variable velocity of wind causes errors in fire which must be allowed for in laying the gun. The deflection leaf on the tangent sight should always be used in making allowance for error due to wind, and the gun should be laid on the object.

Didion gives a formula for calculating the error due to wind;* but as the variability of wind in a long range, both in velocity and direction, is often considerable, no reliable results can be obtained by theory.†

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* *Vide* Didion's "Traité de Balistique," p. 392.

† Colonel Maitland has written a paper on this subject in "Proceedings, R.A. Institution," Vol. VIII. p. 343.

Personal error in laying.

Errors in laying are incident to all systems of laying or sighting, and may be reduced to a small quantity by careful and intelligent gunners when the object can be clearly seen. Constant practice at different ranges is the best way of acquiring this great essential of the gunner's art.

Inclination of the trunnions to the horizon.

Owing to the gun being sighted when the trunnions are horizontal, there arises an error in fire when the trunnions are not horizontal—*i.e.*, when the gun-carriage stands on uneven ground. If the gun is laid by the sights, the projectile deflects towards the side of the lower trunnion.

If h is the height of the perpendicular tangent sight for a given elevation, and the axis of the trunnions is inclined at an angle α, the right trunnion down, the deflection leaf must be increased by $h \sin \alpha$; if, on the contrary, the axis of the trunnions is inclined at an angle α, the left trunnion down, the deflection leaf must be diminished by $h \sin \alpha$.

Unsteadiness of gun, carriage, and platform on firing.

Unsteadiness of the gun and carriage may result from too large a charge being used for the weight of the gun and carriage, causing an excessive jump. The nature of the ground, or platform on which the carriage stands, will have some effect on the amount of jump; also the method of applying the brake on the carriage to check the recoil. If the brake does not act exactly at the same time in each round, there will probably be a variation in the jump of the gun, which will cause an error in fire.

(*To be continued.*)

NOTES ON THE

ORGANISATION AND EMPLOYMENT

OF

SIEGE ARTILLERY.

BY

CAPT. R. WALKEY, R.A.

INSTRUCTOR OF ARTILLERY, R.M.A.

These notes are intended to supplement those on the same subject in the "Handbook for Field Service," 1878. In compiling them, the author has made free use of the following works:—

"Composition and Strength of a Siege Train required for the Attack of a Modern Fortress," by Major Kemmis, R.A. (R.A. Institution Prize Essay, 1877.)
"Attack of Fortresses." Capt. Fraser, R.E. (R.E. Prize Essay, 1876.)
"Experiments in Breaching, at Graudenz," by Capt. Fraser, R.E. (R.E. Professional Papers.)
And "Notes of Sieges," by Kraft, Prince of Hohenlohe Ingelfingen—General Von Decker—and Count Bylandt Rheidt, of the Austrian service.

CHAPTER I.

Altered Conditions of Attack.—First and Second Artillery Positions.—Purposes for which Ordnance are required.—Composition of British Siege Train.—Breaching by Cannelure Cutting with Direct and Indirect Fire.—Practical Directions for Breaching.—Breaching by Demolition.—Necessary Striking Velocity.—Limit of Oblique Fire.—Practical Indications of Progress of Breach.—Notes on Artillery Fire.—*Ammunition:* Principle of Supply.—Rate of Artillery Fire.—Night Firing.—Per centage of Projectiles for British Train.—*Carriages* for Travelling and Firing.—Variety of Carriages.—Protection for Detachments.—Charge of Siege Train.—Site of Field Arsenal.

Altered conditions of attack, owing to increase of range and accuracy of rifled ordnance.

The great power and precision of rifled small-arms and guns, together with the destructive effect of shrapnel on lines of skirmishers, has modified considerably the course adopted when occupying the ground in the vicinity of a fortress.

Supported by the artillery of the place, the skirmishers of the besieged ought to be able to hold their ground during the day at least 1000 yds. to the front, they would probably cover themselves by rifle pits, shelter trenches, &c. The besiegers would have to drive in these skirmishers before their working parties could commence breaking ground, and their outposts would necessarily be at such a distance as not to be exposed to the artillery fire from the place.

Prince Hohenlohe, writing on this subject, says:—"The position of the first batteries will be determined by the ground. I have previously explained that in a defence conducted with energy, the enemy cannot be prevented from establishing his outposts at distances of from 1000 to 2000 paces in front of his works, and consequently the distance of the first batteries from the works will vary between 2500 and 4000 paces, according to the ground. Batteries must be constructed to bombard the place, and drive him away from the ground he is holding in front."

Examples of distances at which 1st batteries can be formed.

In the Franco-German War of 1870, we find that the ranges of the *batteries first constructed* for purposes of bombardment were about 4000 yds., in many instances even further, but this distance is too great to guarantee such certainty of fire as will annihilate the defensive powers of the besieged, effect breaches, or prepare the way for a successful assault.

Necessity of a 2nd artillery position, and its distance.

Therefore a second artillery position nearer to the fortress must be taken up as soon as the guns of the first position have so far driven in the besieged, and engaged the fortress artillery with such decisive result, as to render a second and nearer position tenable. At suitable sites in this position, batteries for direct, curved, and high-angle fire, counter batteries, and batteries for breaching and demolition are constructed.

The distance at which these should be placed will in a great measure depend on the ground; it must be near enough for accurate fire to dismount guns and effect breaches, but should be beyond the limits of infantry fire, and it must be remembered that a heavy expenditure of ammunition is necessary to produce decisive effects with direct fire at ranges above 1600 yds., and with curved fire for breaching over 1200 yds.

Special purposes for which ordnance is needed.

Before stating the natures of ordnance best suited for a siege train, it may be well to consider the special purposes for which ordnance will be required,* viz.:—

1. For general purposes of bombardment—*i.e.*, to destroy buildings, *matériel*, &c., from a great distance.
2. To dismount the enemy's artillery.
3. To form breaches.
4. To keep under infantry fire, effect lodgments, and clear terrepleins.

For bombardment of buildings at the greatest ranges, as the destructive power of the piece depends on the *penetration* and *effect* on *bursting*, of the projectile, the weight and capacity of this latter must be a maximum.

Besides direct fire, high-angle and curved will have to be employed at these long ranges in order to search the enemy's position thoroughly; and, again the heavier the projectile and larger its bursting charge, the better, so that for bombarding purposes generally, heavy rifled guns and heavy rifled howitzers should form some portion of a siege train. When a nearer approach is possible, medium rifled guns and howitzers may suffice for such purposes.

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* For full discussion on this subject, see Major Kemmis' Prize Essay.

An *enemy's guns may be silenced* by (*a*) dismounting or destroying the ordnance, (*b*) by rendering the terrepleins uninhabitable. Ordnance to fight the enemy's guns.

The latter is generally the quicker method, but has a temporary effect only, therefore in the direct attack of a fortress, to render the guns themselves unserviceable will usually be the object of the besiegers' artillery.

If direct fire be employed for this purpose, range, accuracy, and hard hitting are the chief desiderata, all which should be a maximum. This nature of piece should be available for enfilade fire at long ranges, and as great accuracy of fire is required, *guns* would generally be used.

But modern fortresses are provided with so many traverses, and guns are now so securely placed in pits, or close beneath parapets, that howitzers will be needed for curved and high-angle fire, in order to strike them, and destroy the traverses; the larger the shells the better.

For *ordinary breaching purposes*, a piece of medium weight is sufficient, but heavier natures form a breach more quickly, and for breaching by demolition a large shell is important. Ordnance for breaching purposes.

In *driving back the enemy*, and *keeping under infantry fire*, a piece of considerable range, shell power, and mobility is required. Ordnance for keeping under infantry fire.

Finally, ordnance must be supplied for use in the most advanced works to repel sorties, and clear the parapets of men; the work demanded of this nature of piece, necessitating frequently a rapid change of position, its weight should be a minimum. The mountain gun of 200 lbs. appears well adapted for such purposes, and no doubt mitrailleuses would be found very handy by reason of their lightness, whilst the fact of their not recoiling, might enable them to be brought into action where a field piece could not be served.

From the foregoing remarks, it may be concluded that a siege train should consist of—

1. *Heavy* and *medium* rifled howitzers.
2. *Heavy* and *medium* rifled guns.
3. Field pieces, very light guns, and mitrailleuses.

The per centage of the above, to form a siege train, is another matter for consideration.

For convenience of organisation in time of peace, the British siege train is laid down to consist of any number of units composed of heavy and light ordnance, according to the requirements of the service. Composition of "British siege."

The heavy unit consists of—

	No.	Mounted on.
64-pr. M.L.R. guns.....	8	... Siege travelling carriages, and platform wagons.
40-pr. "	8	... Siege travelling carriages.
8-in. M.L.R. howitzers..	14	... Ditto (seven of these 8-in. howitzers provided with beds).
Total	30	

The light unit of—

40-pr. M.L.R. guns.....	10	... Siege travelling carriages.
25-pr. "	10	...
6·3-in. M.L.R. howitzers	10	...
Total	30	

With each of the above units will be associated six 7-pr. R.M.L. guns of 200 lbs., on wrought-iron beds, carried in additional ammunition wagons and store wagons; 300 24-pr. Hales' rockets with six troughs.

Breaching.

Breaching by cannelure cutting.

Until recently, the mode of forming a breach was to cut through by direct fire, that portion of the masonry required to be overthrown, and then either the weight of the superincumbent mass caused its fall into the ditch, or a few shots fired at low velocities, to shake and not penetrate, brought down the separated wall and rampart it supported.

The method adopted was to cut the escarp first in a horizontal, and then in a vertical, direction.

In general, the height of the horizontal cut was $\frac{1}{3}$ that of the wall from the bottom, the length being regulated by the width of the passage required.

The vertical cuttings were made from either end of the horizontal one upwards, and if the masonry was very cohesive, intermediate cuts were made as deemed necessary. The wall was divided into gun portions, and each piece completed its allotment.

Necessary data for breaching by cannelures.

This plan necessitated an accurate knowledge of the profile of the works, the power of observing the striking of the shots, and great accuracy of fire—conditions which, in the days of S.B. ordnance, rendered it necessary to construct breaching batteries close to the fortress attacked.

Example of cannelure breaching.

In 1870, some of the bastions at Strasbourg were breached in this way, at ranges of 790 and 875 yds., the greater accuracy of rifled guns enabling the cutting to be made at such distances. In old fortresses the revetments may still be thus destroyed, but in new works the cordon of the escarp is placed so far below the covering mass that a cutting, $\frac{1}{3}$ the height up from the bottom, cannot be made by direct fire.

Construction of modern fortresses necessitates curved fire for breaching.

In future therefore, breaches will have to be made by indirect or curved fire, unless it is possible to diminish the required angle of descent by cutting away the covering mass first. In some modern works, the profile is such as to necessitate an angle of descent, about 26°, in order to reach the middle of the escarp.*

Greater difficulties of breaching with "curved fire."

The necessity of using curved fire increases the difficulty of forming horizontal and vertical cuttings, for, not only is the fire less accurate (owing to the low velocity and longer time of flight), but the target becomes smaller as the angle of descent increases.

Breaching by "indirect" or "curved fire."

Breaching by curved fire, was successfully employed at the siege of Strasbourg; the right face of Lunette 53 was breached from a distance of about 870 yds., by oblique fire (55°), the angle of descent being 7° 45″. After an expenditure of some 1000 rounds, from the 15 c.m. gun, throwing a shell of 61lbs., a passage was made 108 ft. long at top, and 90 ft. at level of standing masonry, the wall being 4½ ft. thick at top,

* On account of the greater effect produced by elongated shells on bursting, half the height of the wall is now generally considered sufficiently low for the horizontal cutting.

and 6 ft. at bottom: 32 rounds per mètre were thus required for the breach, but it was still in an incomplete state; unfavourable weather, and irregularities from want of practice in serving the guns, materially increased the difficulties.*

For the right face of Bastion 11, with oblique fire 80°, range 875 yds., angle of descent 4° 30″, 20 rounds per mètre formed a breach 96 ft. wide; the horizontal cut was clean and regular at ¼ distance from the base, and after the vertical cuts were made, the wall was thrown down in two large pieces.

Again, in breaching Bastion 12 by front fire, range 790 yds., angle of descent 3° 50′, vertical and horizontal cuts were made with great exactitude, and after 27 rounds per mètre, a nearly practicable breach was made, when the place capitulated; circumstances were particularly unfavourable in the last case.

The above shews† the advantage derived from the greater accuracy and penetration with small angles of descent, as enabling breaches to be more quickly executed, and with a less expenditure of ammunition. By using indirect fire, breaches may be made at very considerable ranges—they can, therefore, be formed at an earlier stage of the siege than formerly. The fact that a practical breach exists, and storming has become possible, will be sure to exert a depressing influence on the garrison, whilst the besiegers will become accordingly encouraged.

General von Decker, in his observations on the use of indirect fire at the siege of Strasbourg, alludes to this as follows:—

1. The breaching facilitated greater rapidity in the engineer's work; and
2. This premature breaching had considerable influence in causing the garrison to decide on capitulating; and "hence it follows that breaches quickly (soon after investment) formed, contribute mainly to the speedy fall of a place." Had direct fire been employed it could not have been commenced for a fortnight later.

Practical directions for breaching.

In the late war the Germans, when breaching unseen walls by indirect fire, derived great assistance from experiments carried out in 1869, and the results of these as afterwards laid down for general use.

The chief difficulty lies in obtaining the exact charge for the given range and angle of descent, others arise from the fact of not seeing the shots strike, and the inability of correcting errors in direction or elevation.

The plan which in 1870 shewed itself most successful, was to fire at some visible part of the wall, and obtain a point of mean impact close to the selected point of aim for the breach. The necessary alterations of elevation to hit the escarp at the height proposed for the horizontal

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* "Prussian Fortresses and Siege Artillery," four parts (from 1870 to 1875).

† No doubt the great difference in the number of rounds per mètre of width needed to breach Lunette 53 was partly due to the fire being very oblique as well as indirect. Observations made after the fortress fell "brought to light that with the combination of charge and angle of descent used there, it had been more of a demolition than a cutting."

cutting was then ascertained, and several rounds fired with the elevation thus found, formed a group of hits from which the cutting was extended on both sides, horizontally, to the proposed breadth of breach. "If it was ascertained by actual observation (from some post distant from the battery) that the position of these groups was correct, the elevating screw was clamped, and the slightly higher elevation necessary as the shots became further removed from the perpendicular, was regulated by the quadrant, whilst the direction was obtained by the new pointing apparatus, which allowed of its being kept very regularly and uniformly, thus ensuring the contiguity of the groups of the shots."

1. Whenever possible, the practice should be observed from some convenient point, and communication be kept up with the battery.
2. The firing—as regards elevation—should be tested several times a day, by very slightly diminishing the elevation, so as to see that the crest is only being just cleared.
3. In the case of front fire, it will generally be best to commence forming the breach at the centre, and thence working to each extremity; whereas, if the fire be very oblique, the horizontal cut should be commenced at that end of the intended breach which is nearest to the battery.
4. If several guns are engaged in forming the breach, it may be well to commence cutting the horizontal line from each extremity, half the guns grouping their shots on one end of the breach, and half on the other, and working inwards.
5. The shifting of the group of hits right or left, as the case may be, can perhaps be most accurately done by using the deflection scale, and maintaining the same point of aim.
6. A record of the correct deflection and elevation for each group of hits should be kept, so that when passing along the horizontal line a second time to deepen it, exactly the same laying may be obtained.
7. The line along which it is intended to form the horizontal cut having been fixed, an angle of descent—just clearing the parapet—should not be calculated in reference to a point on this line, otherwise, half the shots will be interrupted by the covering mass; but, a spot being selected half the vertical spread of the gun below this line, the proper charge and elevation to strike this point should be found, and the trajectory afterwards raised this height; in this way the "line of mean vertical deviation" will be the central line along the horizontal cutting.*

Breaching by "demolition."

The difficulty of cutting cannelures by curved fire being foreseen, experiments were carried out on the continent to breach by destroying the revetment from the cordon downwards, thus gradually wasting the

* "In order not to lose 50 per cent. of the shots, fire at a point somewhat above the *lowest* point of impact, but with the maximum angle of descent required to reach the lowest point."—*French Official Text Book, 1876, Translated by Capt. Fraser, R.E.*

wall away down to the depth necessary. In this case, the projectile falling from a height, cuts downwards as well as into the masonry, and if the action of the fuzes be restrained till the shell has penetrated its full distance, the effect of large bursting charges is very marked.

In 1873, the Prussians experimented at Graudenz with 12, 15, and 21 c.m. guns, to compare the methods of breaching, by cutting cannelures and by simple demolition of the upper half of the wall, slow percussion fuzes—exploding one second after striking—being used.

Experiments at Graudenz to compare breaching by demolition and by cutting cannelures.

Results are stated thus (having regard to the 15 c.m. gun): "The circumstances were more favourable for 'cutting' than for 'demolition,' whilst in the former case the angle of impact was 75°, and the striking velocity 770 f.s., in the latter they were 57°, and 669 f.s., respectively. Notwithstanding this, it would have required, in the first instance, 63 hits per mètre of the width to make a practical breach; in the second instance, only 52 hits per mètre would have been necessary."

This result confirms French experiments, that "by simple demolition instead of cutting, a practicable breach can be made with a less expenditure of ammunition, and that a practicable breach can be made by demolition, where the lowest point of striking is half way down the wall, whilst an immediate observation of the breach is not at all requisite."

Conclusion formed by German officers at Graudenz.

The result of these trials was indeed so favourable, as to justify the opinion that "circumstances, favourable to cutting, will rarely occur in war, so that this mode of firing will be the exception." Whilst Count Bylandt Rheidt, of the Austrian service, says "the mode of demolishing the upper half of escarps by means of curved fire will in future supersede the old plan of cannelure cutting."

Consideration of which method of breaching to employ.

Particular local circumstances must be the guide in each case, as to which method of breaching is likely to prove the more advantageous. It should be borne in mind that when the masonry is weak, the cutting system would require to destroy less of it; and that if direct fire can be used, and an immediate observation of the striking of the shots be obtained, this system is likely to be the quicker; but the execution of horizontal and vertical cuts becomes considerably more difficult with an increase of thickness of wall, whilst this difficulty is added to as the angle of descent becomes greater. Breaching by demolition appears advantageous as destroying counter-arches more effectually, so that these fall with the masonry instead of remaining standing as was often the case when cannelure cutting was employed, their after destruction was always difficult; further, less accuracy is necessary (an important point in the case of curved fire), the masonry falls in smaller blocks, thereby forming a more accessible breach, and the wall is attacked at its weakest part.

Comparison of guns of different calibres for breaching.

Further conclusions, derived from the Graudenz experiments, state "the practicability of demolition at angles of descent to 15° may be accepted; and, in regard to the relative breaching powers of guns of different calibres, a comparison of the 15 c.m. and 21 c.m. guns, at all stages of the experiments, gave proportional results—that is to say, with the same striking velocities an equal weight of projectiles was required to produce equal results. The advantage of the heavy calibre

is therefore not to be sought in the use of less ammunition, but in other factors; these are, time and accuracy—a reduction of time required for breaching will always be important and necessary. The superiority of single shots will be especially valuable against bombproofs, covered from a high angle of descent, as under some circumstances, a single shot might suffice to penetrate and render them untenable at an early stage of the attack."

Further it may be stated, that a certain normal energy being necessary for penetration, this may be obtained more readily from a heavy than a light projectile, because a lower striking velocity will be needed by the former, to do the same work; in the case of high-angle fire, the required angle of descent can, therefore, be more easily obtained.

Normal energy necessary to penetrate revetments.

No satisfactory experiments have been made in this country to determine the different resisting powers presented by walls of stone, masonry, or faced concrete; thus there are no data for estimating the normal energy necessary to any particular projectile, to penetrate various revetments.

At the siege of Strasbourg, the gorge wall of Lunette 44, was destroyed from a distance of 960 yds.; angle of descent, 11° 45′; striking velocity, 475 f.s.; ordinary masonry; gun, 21 c.m. mortar (8·23-in. calibre).

The normal velocity of impact would be

$$475 \times \cos 11° - 45' = 475 \times \cdot 98 = 465 \text{ f.s.}$$

Total normal energy

$$= \frac{wv^2}{2g} = \frac{176 \times 465^2}{64{\cdot}4 \times 2240} \text{ ft. tons} = E'.$$

Normal energy per inch of shot's circumference

$$\frac{E'}{\pi \times 8{\cdot}23}.$$

In 1824 some experiments were made in breaching by curved fire, the ordnance used being 10-in. and 8-in. howitzers, and 68-pr. carronades; the elevations ranged between $13\frac{1}{2}°$ and 14°; the charges between 1 and 2 lbs. A breach, 14 ft. wide, was made after an expenditure of 1400 rounds; the striking velocities have been calculated at 253, 254, and 284 f.s.; the energy would thus be 40, 20·3, and 36·9 ft. tons. We see therefore, that very moderate velocities would give 40-pr. shells sufficient energy (measuring by equality of $\frac{wv^3}{2g}$) to breach ordinary revetments. For the 40-pr., 377, 269, and 362 f.s. would be equivalent velocities to those above-named.

For the 12 and 15 c.m. guns, the Germans consider 220 and 160 mètres the lowest limit of striking velocity for breaching.

In the case of using projectiles of different diametres, the necessary normal energy "per inch of shot's circumference" being known, the normal velocity could be calculated, and the requisite striking velocity for any angle of descent.

Sometimes the point at which it is required to strike the revetment may be reached with a less angle of descent, by firing more obliquely to the wall, so that there may be a greater distance between the crest of the glacis and the escarp, but it must be borne in mind that this obliquity of fire will reduce the normal energy of impact.

It was partly to obtain a less angle of descent by allowing the projectile to traverse a greater width of ditch, that in the siege of Strasbourg Lunette 53 was fired at so obliquely.

Limit of oblique fire for breaching.

The limit of oblique fire depends somewhat on the material of the wall; for common masonry, it is considered to be between 55° and 60°; as stated, Lunette 53, at Strasbourg, was breached at a horizontal angle of 55°, the material being red sandstone; "at first many shots were seen to glance, and on account of the difficulty of making first impressions on the wall by single shots, two salvoes were fired from four pieces with the same aim, then a third salvo was fired at a spot distant 3 ft. laterally." When the surface of the wall is once broken, glancing becomes less likely.

A ravelin of the fortress of Graudenz was breached by demolition, the horizontal angle of impact with the face of the wall being 57°—42′ whilst the angle of descent was 7°, and striking velocity 673 f.s.; in this case—thought to be the extreme limit for long shells—none of the projectiles glanced.

The French consider that the angle of obliquity should not be less than 60°.

The velocity normal to the wall varies as the sine of the angle of obliquity.

Practical indications of progress of breaching and penetration of shell.

The noise of impact on masonry is sharp: when the wall is cut through the sound is dull, and the same is the case when a shell strikes earth. The deeper the penetration in masonry, the longer the smoke takes to rise.

Till the wall is cut through the smoke is bluish-white, white or red with brickdust. When shells burst in earth behind a revetment, which has been cut through, the smoke is dark-grey and rises as out of a chimney. At Graudenz, splinters were observed to come back at least 400 yds. from the masonry.

Notes on artillery fire generally.

In general, decided results will be more expeditiously obtained by a concentration of fire on the ordnance, breach, *matériel*, or troops to be attacked, then, the object once attained—occasional rounds being fired to prevent re-armament or repairing—the mass of guns can concentrate on some other point.

As a rule, in enfilading by means of curved fire the flatter the trajectory and the higher the striking velocity* the greater will be the effect; as the angle of descent increases, and "high-angle fire" is approached, the striking velocity usually becomes less, whilst the shells striking down into the earth will not do so much damage to troops or *matériel* on the terrepleins.

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* In certain cases a low velocity may be an advantage—*e.g.*, if it be desired that the pieces should fly *back* from the burst; when shells with a very high velocity burst, most of the pieces go forward.

Very oblique fire, with a high-angle of descent, is the least favourable for penetration.

When employing curved or high-angle fire to breach or bombard, the largest admissible charge should be used in order that the striking velocity may be high, the penetration considerable, and the bursting effect consequently great. Therefore, for a certain angle of descent, provided that accuracy be not unduly sacrificed, a long range is of advantage, as enabling a heavier charge to be employed.

Night firing will be more accurate if the detachment who have served the gun by day also used it by night, firing at the same object with the same range. The accurate knowledge of the object's appearance, which the day's practice has given, may, in some cases, enable the men to recognize the spot on which the shell struck by its flash on bursting; and by day, trial shots can be made, using that method of laying about to be employed during the night. If intended to prevent repairs being executed, night firing should take place at *irregular* intervals.

Ammunition.

Ammunition: circumstances which regulate amount.

The total ammunition necessary for a siege train, must evidently depend on the duration of the siege; the principle of supply being, that there should be sufficient ammunition for each piece to provide against any cessation of fire through the lack of it, until the fortress is taken.

A certain amount of ammunition must, therefore, be provided before firing commences, and then reserves must be at hand to replace daily expenditure.

Prince Hohenlohe says:—"In order to avoid any cessation of fire, twice the daily consumption is stored in the battery in magazines; the men forming the new relief bring with them, from the intermediate depôt, the prescribed daily allowance to replace the expenditure. If the consumption has varied, the commander of the battery who is relieved, reports to that effect, and the next relief brings up a greater or less number of rounds."

Some pieces are required to continue firing throughout the whole period of the siege—such as those for bombarding purposes, and for clearing the parapets of men; were such to cease firing, the enemy might construct other cover or execute repairs; further, there is the object of giving the enemy no rest and making him feel continually unsafe.

Other ordnance—such as those for breaching, enfilading, and fighting the artillery of the besieged—are required to fire rapidly and continuously for days together until they have attained their special object; afterwards, only occasional rounds are needed by day and night to prevent repairs being carried out.

The expenditure by field and very light ordnance must vary according to the activity of the garrison.

Rate of artillery fire in sieges.

Rapidity of fire should always be sacrificed to accuracy and steadiness; moreover, as far as possible, the firing should be regulated by observation either from the battery, or some post which can communicate with the battery by signal.

Certain batteries may require to fire very briskly for a time; 15 rounds per hour by day, and half the number by night, would seldom be exceeded for any length of time.

Indirect fire for breaching would be usually less rapid than direct. By night, except in cases of attacks or sorties, only sufficient rounds to prevent repairs by the besieged would be fired.

Prince Hohenlohe states in regard to rate of fire, that "a daily allowance of 50 or 60 rounds per gun gives a very brisk fire, more than this has not generally seemed desirable," and adds "the above rate was not often exceeded. During the last war the Germans seldom fired more than 8 rounds during any hour of daylight, generally not more than 3 or 4, and fewer at night."

The French official handbook (1876) gives the following as the lowest supply considered proper for one day (24 hrs.) :—

60 rounds for each heavy gun.
80 " " medium or light gun.
40 " " mortar.

Night firing.

The use of hanging scales greatly facilitates night fire; the lines of sight to different objects being painted on the platforms by day, should be marked stating the object and elevation, if this be carefully done—elevation being given by the quadrant—there is no reason why night firing should not be almost as accurate as day.

Another plan is to use the sights proposed by Captain French, C.M.G., R.A.,* pointing rods being fixed by day in the plane of sight behind the gun, a lantern placed on the rear rod will indicate the proper direction by night.

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* The following description of the sights proposed by Capt. French, C.M.G., R.A., is added, as by them ordnance may be laid by day or night with far greater accuracy than can be obtained from the ordinary hanging scales. By their employment, guns may be placed in any hollow or depression of ground—behind hills, ridges, or woods—and, whilst unseen by the enemy, inflict on him a maximum amount of damage.

Two similarly graduated bars, about 6 or 8 ins. long, stand out horizontally from the ordinary trunnion sight and tangent scale, a small sight is free to move along each bar. The zero on each bar is equidistant from the axis of the gun, consequently, if the travelling sights are moved to 1, 2, 3, in inches or degress from the zero, in each case they will be parallel to the axis. They are used in the following manner :—

A plummet is suspended some 6 or 8 yds. in rear of the platform, so as to be as nearly as possible in the same vertical plane as the centre of the bars and the object, a second plummet is suspended 8 or 10 yds. in rear of the first (a line on a board, picket, or other mark, will do as well), also in the same vertical plane as the first plummet and the object. In laying the gun, No. 1 moves round in front of the trunnion, and looking back on the two lines in rear observes where the vertical plane passing through them cuts the front bar; let us suppose that it cuts the bar at the mark 2, he then clamps the moveable sight there, moves to the hind bar and clamps the sight on it at the same division 2; looking over the trunnion sight on to the line in rear, he will probably see that the sight on the hind bar is a little to the right or left of this line, the gun is then traversed till the two sights are in line, when, consequently the gun becomes laid with its axis parallel to the plane of sight. There is a deflection scale on the inner end of the tangent scale bar. For night firing, a lamp with two wires (crossing each other in front of the light) takes the place of the *further* plummet or picket. This means of laying guns, howitzers, or mortars, without seeing the object (or being seen therefrom), has been tried at Shoeburyness, and reported as "absolutely correct."

Recent Russian trials with night fire to find its effects.

In 1875, experiments were carried out in Russia to try the effect of night fire with shrapnel, the object being to ascertain whether working parties could be prevented repairing a damaged parapet.

Firing took place at a range of 1166 yds. from two 24-prs., weight of shell 78 lbs. (containing 230 bullets), time fuzes. The gun was laid by means of two pickets 47 yds. apart, planted by day in the plane of sight to the front of the gun. Elevation having been given by quadrant, the tangent scale was raised a convenient height to give a line of sight on to both pickets; at the point where this line cut each picket, a lantern was placed by means of a sliding ring. The tangent scale being clamped, the gun was laid by it on the lanterns. 56 dummies were spread over the ruined parapet, and 20 shells were fired; it was found that 45 dummies were struck by 201 bullets or pieces of shell, the conclusion arrived at being "that the repairs of parapets even by night can only be effected with a risk of great loss."

Ammunition allotted to commence siege, "British train."

For a British siege train 500 rounds per piece of ordnance composing the unit has been allotted as the quantity necessary to commence a siege with.

In reference to the above, Prince Hohenlohe states—"the necessary store of ammunition has fluctuated in practice between 300 and 500 rounds per gun."

The following table shews the per centage of the various projectiles:—

Nature.		Com. shell.	Shrapnel.	Battering.	Case.	Star.	Carcases.	Dble. shell.
Heavy unit.	64-pr.	60	30	8	2	—	—	—
	40-pr.	60	36	—	4	—	—	—
	8·3-in. howitzer	90	—	—	2	2	6	—
	7-pr.	30	—	—	—	—	—	70
Light unit.	40-pr.	68	30	—	2	—	—	—
	25-pr.	60	36	—	4	—	—	—
	6·3-in. howitzer	90	—	—	2	2	6	—
	7-pr.	30	—	—	—	—	—	70

Carriage of powder.

To avoid the inconvenience of carrying and storing powder in bulk, also to save time, and for greater security, all cartridges are to be carried filled in metal-lined boxes, all shells are to be filled, and together with the case shot, carried in wooden boxes.

Carriages.

Carriages.

Each piece of ordnance must be provided with a carriage for firing from, the description of which will vary with the nature and purpose of the piece.

It is important that as heavy ordnance as possible should be brought up, the maximum weight for transport by 12 horses (more cannot be advantageously employed in one team) is calculated to be 100 cwt.; this weight must, therefore, not be exceeded by the gun on its transport carriage.

The possession of railways leading to important fortresses would of course enable heavier natures of ordnance to be brought forward for siege purposes, but the limit of weight for transport will usually limit the weight of ordnance composing a siege train, unless guns be constructed of different parts capable of being conveyed on separate carriages.

But "firing carriages" must necessarily be made much stronger than is required for transport, so that more powerful ordnance can be taken by carrying them on some such wagon as the "platform wagon," and either letting the firing carriages also be transported, or, if siege travelling carriages be employed, by allowing them to travel empty.

Advantages of guns travelling on their firing carriages.

The 64-prs., therefore, usually travel on platform wagons; whilst lower natures, whose weight with that of their firing carriages does not approximate very closely to 100 cwt., move on their firing carriages; by this means fewer horses are required, fewer carriages compose the column (whose length is accordingly shortened), no shifting of gun from transport to firing carriage is needed, and the gun can be brought into action more quickly.

Variety of carriages.

Carriages are needed for "high-angle," "curved," and "direct fire."

The new iron siege travelling carriages are especially constructed to allow of high-angle and curved fire from them, whilst beds are also furnished for the 8-in. howitzer and 7-pr.

As regards "direct fire," a difficulty arises, owing to the great accuracy of rifled ordnance, such fire must take place either from guns mounted *en barbette*, or in ordinary embrasures.

Experiments in firing at guns "en barbette" and in embrasures.

Recent experiments at Eastbourne, in 1876, shewed that ordnance mounted to fire over a parapet would, at a long range, be very quickly disabled by guns firing on the same level.

In 1875 also, experiments were made in Russia, to ascertain the requisite number of rounds to dismount guns placed in different positions :—

1. A gun, *en barbette*, unprotected. (24 rounds dismounted the gun and killed all the dummy detachment.)
2. A gun behind an ordinary embrasure. (The gun met with the same fate after 10 rounds, the embrasure being completely destroyed.)
3. A gun, mounted behind a shallow embrasure, at a certain distance from the interior slope, close to the rear edge of the terreplein. (The gun was dismounted, with the loss of all the detachment, after 52 rounds, the shallow embrasure being transformed into a trench, 3 ft. deep, by 10 ft. broad.)

The firing was from a 24-pr., distant 1166 yds., with common shells and Prussian percussion fuzes.

Remarks state "it was found that the gun behind the embrasure was the easiest to dismount, because it offered a larger object."

General Todleben's opinion.

General Todleben's opinion was expressed thus :—"Direct laying is only possible from guns *en barbette*, or from those firing through an ordinary embrasure, two methods which, now-a-days, are inadmissible."

Expediency of cover for guns and detachments.

For direct fire, the new overbank carriage would be generally used in our service. A gun mounted on it presents but a small mark to the enemy, and the gunners working it are to a great extent protected. To conceal the gun itself more effectually, it might be of value to adopt some carriage on the Moncrieff principle, allowing the gun to be loaded and laid under cover of the parapet, whilst easily elevated to fire over the parapet; it has also been suggested that the guns be mounted on low garrison sliding carriages, the platform being on a revetted bank of earth, just raising the piece high enough to fire over the parapet, whilst the detachments are partly under cover.

Charge of siege train.

A siege train appointed to an army for general siege work, usually remains at the base of operations under charge of the Ordnance Department, until a siege is decided upon, when the ordnance with their equipment are moved forward to the *field arsenal*. On account of the increased extent of front, now occupied by the attack, it is probable that in future more than one such arsenal will be required. In recent sieges, several have been formed from $3\frac{1}{2}$ to $4\frac{1}{2}$ miles from the place, and when necessary, intermediate depôts made between them and the trench magazines, so as to replace the daily expenditure with as little labour as possible. The French official instructions say :—"If the lateral communications be bad, several artillery parks may be required. —The main park to be, say 8700 yds. from the fortress.—The main powder magazines should be in secure positions, 200 yds. apart, and should hold from 120,000 to 240,000 lbs.—Intermediate depôts for 24 hrs. supply are placed in rear of the first artillery position.—Each battery to have two powder magazines."*

Field arsenal.

The site of the field arsenal is usually fixed when the investment has taken place, it must be as central as possible, well out of range of the enemy's guns, and at such a distance as to be secure against any sortie; if there be communication by rail, much labour will be saved by placing it near the line.

This arsenal, also in charge of the Ordnance Department, should contain a reserve of guns and carriages, together with platforms, and the various artillery stores and machines necessary for prosecuting the siege; also the general powder magazine for shell filling. From its reserves constant issues must be made to supply the daily expenditure of the various batteries, or replenish the supply of any depôts or parks intermediate between it and the trench magazines.

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* "R.E. Institute Papers," Vol. II., 1878. Capt. Fraser, R.E.

THE CASTING OF THE 100-TON GUN IN THE TURIN GUN FOUNDRY.

(Translated from the "Italia Militare.")

CONTRIBUTED BY

LIEUT.-GENERAL H. H. MAXWELL, C.B., R.A.

On the morning of Wednesday, the 30th January, 1878, there was cast in the gun foundry of Turin a gun of a calibre of 45^{cm} (17·72-in.), which when finished will weigh 100 tons. The casting took place in the presence of the General Commanding the Division, General Bonelli, the General Commanding the District of Artillery, and General Rosset, the Director-General of Artillery, who proposed the gun and the method of its construction as far back as the 1st February, 1875.

The casting, whether for its size, or still more for the limited means available for the work, is certainly one of the most important ever executed in Italy, and one the success of which assuredly does much honour to our artillery. We may, therefore, expend a few words in demonstration of the importance and difficulty of the work.

The 100-ton gun under construction is of cast-iron, breech-loading, hooped with three concentric strata of steel rings, analogous to the 24 and 32^{cm} (9·45 and 12·20-in.) guns. Its total length is 10 mètres (32·8 ft.), the calibre is 45^{cm} (17·72 ins.), the external diameter of the hooped part is 1·862 mètre (5·92 ft.) It is to fire a projectile of about 1000 kilogrammes (2205 lbs.) The cast-iron part of the gun—that which has just been run—will weigh, when finished, about one-half the weight of the finished gun.

The system of casting adopted was that of Rodman, now in use for other guns of large calibre—that is, the siphon method, with a core cooled from the inside by cold water. The mould, of dry sand enclosed in keyed-up cast-iron boxes, was placed upright in a pit dug on purpose, and strutted up firmly therein. Three siphons of different lengths, opening into the mould tangentially, carried the metal in succession into the mould from the channels immediately above them. Inside the core, made of a tube of wrought-iron covered with loam, was the water-pipe. The mould measured 13 mètres (42·7 ft.) in length over all; its internal cavity for the gun and deadhead was 12 mètres

(36·1 ft.), having a maximum diameter at bottom of 1·23 mètre (4 ft.), and a minimum diameter at top of 0·87 mètre (2·85 ft.), so that the breech of the gun was downwards. The core had a maximum diameter at bottom of 40^{cm} (1·3 ft.), and a minimum above of 34^{cm} (1·1 ft.)

To fill such an enormous cavity and its siphons there was required a mass of some 66 tons of cast-iron. This would have involved no great difficulty if reverberatory furnaces capable of containing the full charge had been built round the pit; but no such appliances existed, nor was it deemed advisable for a mere first experiment to spend a large sum of money in building new furnaces. Thus the foundry, confined to existing constructions, was compelled to face the exigencies of the casting with four large reverberatory furnaces standing round the pit capable of holding a charge of 40 tons, and six small reverberatory furnaces capable of holding a charge of 27 tons, but situated in a neighbouring building at a distance of from 80 to 100 yds. from the pit. The metal to replace casual loss, and to feed the deadhead on the shrinking of the casting, was to be furnished from old guns run down in a small furnace.

The transport of the metal from the smaller reverberatory furnaces to the pit was effected by three ladles capable of containing 9 tons each. They were manœuvred by the foundry hydraulic crane.

The operation of casting was brilliantly successful. The transport of the molten metal in successive trips took 35 minutes; the metal of the ladles, mixed with that of the reverberatory furnaces, passing through the channels, poured down the siphons and filled the mould in 19 minutes; after which the water was turned on to circulate in the core, to initiate the cooling. The feeding of the deadhead was carried on for 4 hours, requiring a little more than 5 tons of metal.

Judging from the regular and precise way in which the casting was effected, it may be taken as highly probable that the block will be perfect.

The transport of such an enormous amount of molten metal, combined with the necessity of a rapid and uniform flow of the whole mass properly mixed, constitute without doubt an operation of unusual difficulty; and the excellent result is a proof that every arrangement necessary thereto had been properly made. The success redounds to the credit of the General who proposed the gun, of the intelligent direction of Colonel Giovanetti, and of the co-operation of the hard-working establishment of the Turin foundry, among whom the foreman, Mr. Daguino, deserves especial mention.

In a few days the work on the casting will be commenced, and we may reasonably hope that it will be completed in a year.

PRINCIPLES OF GUNNERY.

RIFLED ORDNANCE.

BY

MAJOR J. SLADEN, R.A.

PROFESSOR OF ARTILLERY, R.M. ACADEMY, WOOLWICH.

(*Continued from p. 432.*)

CHAPTER IX.

The Penetration of Projectiles.

Energy absorbed in Penetration.—Energy absorbed in Perforation.—Method of estimating the Resistance to the Projectile.—Formulæ for calculating Perforation of unbacked wrought-iron Plates.—Materials used for Armour-Plates: Cast-iron, Wrought-iron, Steel.—Compound Plates.—The form of Head of Projectile.—Energy required to Perforate a Plate obliquely.—Material of Projectile.—Armour Plates with intervals between them.—The Effect of Common Shell on Armour-Plates.—The Effect of Palliser Shell with wrought-iron points.—Wood.—Earth.—Masonry.—Concrete.

No accurate experiments have as yet been carried out in order to determine the coefficients of resistance for the different materials of projectiles and plates, so that it is difficult to study the subject advantageously in a rigid mathematical way; but practically the amount of penetration, whether for iron or steel plates, or masonry, or earth, has been determined by actual experiment. Various empirical laws have, from time to time, been brought forward, which have sufficed to give approximate results for experimental purposes, but they have not stood the test of any general application. There are, indeed, so many varying conditions which take place in actual experiment that it is almost impossible to apply practically strictly analytical investigations —for instance, the varying qualities of resistance both in projectiles and targets, the variation in shape of the projectile on impact, the possibility of the projectile breaking up, and the amount of heat developed on impact. Such investigations may be studied in Didion's "Traité de Balistique," p. 285 *et seq.*; but in the following pages the subject will be considered in a more experimental way, and the penetrative effect of projectiles against iron, steel, wood, earth, and masonry will be considered in detail. Generally speaking, the penetrative effect depends on the shape and material of the projectile, on its energy, and diameter, and the direction with which it strikes the target.

Energy absorbed in penetration.

It is evident that if a projectile has not sufficient energy to perforate a resisting medium, it will penetrate a certain distance until its energy has been absorbed by the resistance.

Suppose, then, W = weight of projectile in lbs.,
V = velocity on impact in feet per second,
R = resistance in lbs.,
s_1 = number of feet penetrated,

then
$$\frac{WV^2}{2g} = Rs_1; \quad \text{.....(1)}$$

if the resistance be supposed uniform.

Energy absorbed in perforation.

But if the projectile has sufficient energy to perforate, the remaining velocity can be measured after perforation by means of a chronograph, and the energy absorbed in perforating the resisting medium

$$= \frac{W}{2g}(V^2 - v_1^2);$$

where v_1 is the remaining velocity immediately after perforation.

Hence, in this case,

$$\frac{W}{2g}(V^2 - v_1^2) = Rs_1 \text{.....(2)}$$

But if R (the resistance to the projectile) be *variable*, the equation must be written

$$\frac{W}{2g}(V^2 - v_1^2) = \int_0^{s_1} Rds. \quad \text{.....(3)}$$

Differentiating (3), considering v and s as variable,

$$R = -\frac{W}{g} v \frac{dv}{ds} = -\frac{W}{g}\frac{dv}{dt},$$

then
$$\int_{t_1}^{0} Rdt = -\frac{W}{g}\int_{v_1}^{V} dv;$$

or if t_1 = the time of perforation through the resisting medium (resistance supposed *uniform*),

$$R = \frac{W}{g}\left(\frac{V - v_1}{t_1}\right). \quad \text{.....(4)}$$

Substituting in (2), then

$$\frac{W}{2g}(V^2 - v_1^2) = \frac{W}{g}\left(\frac{V - v_1}{t_1}\right) s_1,$$

or
$$t_1 = \frac{s_1}{\frac{1}{2}(V + v_1)}; \quad \text{.....(5)}$$

or the time of passing through the resisting medium

$$= \frac{\text{thickness of resisting medium}}{\text{mean velocity of projectile in passing through the resisting medium}}.$$

If v_{11} is the velocity which would be required *just to perforate* the resisting medium, it follows that

$$\frac{W}{2g} v_{11}^2 = Rs_1;$$

but
$$Rs_1 = \frac{W}{2g}(V^2 - v_1^2) \text{ from (2)},$$

hence
$$v_{11} = \sqrt{V^2 - v_1^2}.$$

Method of estimating the resistance to the projectile.

The mean resistance, R, is the total force acting on the projectile in lbs.; and knowing R, the resistance in lbs. can be calculated either per inch of circumference or per square inch of sectional area. For instance: suppose $R_{,}$ is the resistance per square inch of projectile's sectional area, and $R_{,,}$ the resistance per inch of projectile's circumference, then

$$R = R_{,}\tfrac{1}{4}\pi d^2 = R_{,,}\pi d,$$

$$\text{and } R_{,,} = \tfrac{1}{4}dR_{,};$$

where d is the diameter of the projectile in inches.

So that if the energy per square inch of projectile's sectional area be required, so as just to perforate a resisting medium, we have

$$\frac{Wv_{,,}^2}{2g} \cdot \frac{4}{\pi d^2} = R_{,}s_{,}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

or if the energy per inch of projectile's circumference be required,

$$\frac{Wv_{,,}^2}{2g} \cdot \frac{1}{\pi d} = R_{,}s_{,}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

The question then arises, which method most nearly agrees with the results of experiment? For thin plates, which can be easily perforated, experiment seems to show that the projectile acts as a punch, cracking the plate *circumferentially*, as in Fig. 2, at the same time slightly bulging the plate, which commences to crack on the inside during perforation, as in Fig. 1. In this case the method of estimating the resistance per inch of projectile's circumference gives the

Fig. 1.

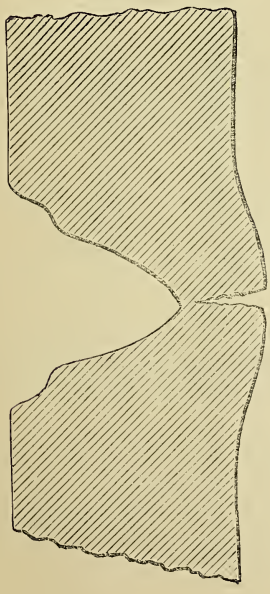
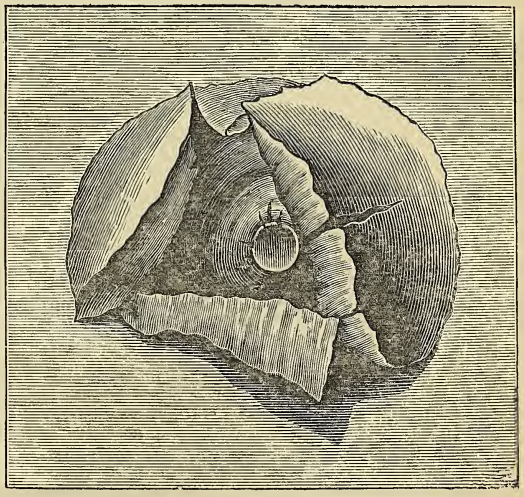


Fig. 2.



best results; but in cases where the projectile acts as a wedge and drives the resisting material before it—*e.g.*, in the case of penetration into earth—the method of estimating the resistance per square inch of sectional area gives approximately the best results. The truth probably lies between these methods of estimation, inclining more to the one or the other according as a punching or a wedging action is brought into play.

Formulæ for calculating perforation of unbacked wrought-iron plates.

The formulæ which have given good results within certain limits on the supposition that the thickness to be perforated may be estimated from the energy per inch of projectile's circumference, are of the form

$$\text{energy in ft. tons per inch of circum. } (E) = k \times \{\text{thickness of plate in ins. } (s)\}^x;$$

where k and x are coefficients which must be determined by experiment.

The formula adopted in the Department of the Director of Artillery, given by Major W. H. Noble, R.A., is

$$E = ks^x,$$

where $k = 2{\cdot}53$ and $x = 1{\cdot}6$; so that

$$s = \left(\frac{E}{2{\cdot}53}\right)^{\frac{1}{1{\cdot}6}}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

These constants are computed for ogival-headed Palliser projectiles* and wrought-iron plates, and within certain limits give approximately correct results for plates that can be perforated. Captain Andrew Noble, F.R.S., gives

$$s = \left(\frac{E}{3{\cdot}18}\right)^{\frac{1}{1{\cdot}6}}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Colonel Maitland, R.A., has calculated a formula from experimental data, on the supposition that the thickness to be perforated may be estimated by the energy per square inch of projectile's sectional area—viz.,

$$s = \frac{E}{(4{\cdot}733)\pi r^2} = \frac{E}{14{\cdot}87r^2}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where E represents total energy in ft. tons on impact, and r the radius of the projectile in inches.

As an example of calculating the thickness of plate that may be perforated, suppose the energy per inch of circumference of a Palliser shell on impact is known to be 165·6 ft. tons; then by formula (1),

$$s = \sqrt[1{\cdot}6]{\frac{165{\cdot}6}{2{\cdot}53}} = 13{\cdot}6 \text{ ins.}$$

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* More correct results are given with steel projectiles.

It is found that this formula gives good results when the plate can be perforated; but for a very thick plate which cannot be perforated it does not follow that the penetration of the shell will be 13·6 ins., but the result may be approximated to in many cases by allowing a deduction of about 10 per cent.—*i.e.*, the actual *penetration* of the above shell into a wrought-iron armour-plate of considerable thickness may be approximated to at about 12·3 ins.

Table showing Approximate Energy in foot tons per inch of Shot's Circumference required for the Perforation of Unbacked Iron Plates by Steel Shell.

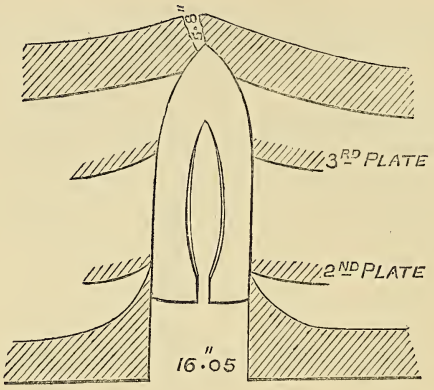
Thickness of plates.	Energy per inch of circumference.	Difference.	Thickness of plates.	Energy per inch of circumference.	Difference.
ins.	ft. tons.		ins.	ft. tons.	
4	25	4	22·5	368	13
4·5	29	5	23	381	13
5	34	5	23·5	395	14
5·5	39	6	24	409	14
6	45	6	24·5	423	14
6·5	51	6	25	437	14
7	57	6	25·5	451	14
7·5	63	7	26	465	14
8	70	7	26·5	479	14
8·5	77	7	27	494	15
9	84	8	27·5	509	15
9·5	92	8	28	524	15
10	100	8	28·5	539	15
10·5	108	9	29	554	15
11	117	9	29·5	569	15
11·5	126	9	30	585	16
12	135	9	30·5	601	16
12·5	144	9	31	617	16
13	153	9	31·5	633	16
13·5	162	10	32	649	16
14	172	10	32·5	665	16
14·5	182	11	33	682	17
15	193	11	33·5	699	17
15·5	204	11	34	716	17
16	215	11	34·5	733	17
16·5	226	11	35	750	17
17	237	11	35·5	767	17
17·5	248	11	36	785	18
18	259	11	36·5	803	18
18·5	270	12	37	821	18
19	282	12	37·5	839	18
19·5	294	12	38	857	18
20	306	12	38·5	875	18
20·5	318	12	39	893	18
21	330	12	39·5	911	18
21·5	342	13	40	929	
22	355				

Calculated from the equation $E = 2{\cdot}53s^{1{\cdot}6}$ (Major Noble's formula), E being the energy in foot tons per inch of the shot's circumference required to perforate a plate of s ins. in thickness.

It has been ascertained by experiment that projectiles of similar forms of head and different calibres require approximately the same amount of energy per inch of circumference to perforate the same armour when the plate is not much thicker than the diameter of the projectile; but when the plate is more than one-fourth thicker than

the diameter of the projectile, the energy per inch of circumference must be in a much higher proportion in order to obtain perforation.

The 80-ton gun was fired against a target consisting of four 8-in. plates, with 5-in. layers of teak between each plate. This target had a total thickness of 32 ins. of iron. The energy per inch of projectile's circumference was about 589 ft. tons, which should according to formula (1) perforate a solid iron plate without backing of 30·16 ins.



The actual penetration was 27 ins., but "the point was visible through large cracks in the back of the target, in some places open to a width of $2\frac{1}{2}$ ins. There was about 5·8 ins. of iron still in advance of the point, but this was fissured and opened in a star crack. The back plate was bent back nearly 14 ins."*

Types of Ships' Armour, with the Energy per Inch of Circumference required for Perforation.

Inches of iron in target.	Inches of wood in target.	Skin of iron.	Energy per inch for perforation.	Inches of iron in target.	Inches of wood in target.	Skin of iron.	Energy per inch for perforation.
		ins.	ft. tons.			ins.	ft. tons.
4·5	10	none	34	12	12	$1\frac{1}{2}$	182
5	9	$\frac{1}{2}$	42	13	14	$1\frac{1}{2}$	204
5·5	10	1	51	14	12	$1\frac{3}{4}$	226
6	12	$\frac{1}{2}$	60	15·5	12	$\frac{3}{4}$	237
6	30	none	70	14	10	$1\frac{1}{2}$	259
8	10	$\frac{3}{4}$	84	17	19	$1\frac{3}{4}$	306
8·5	15	none	96	18	18	$1\frac{3}{4}$	330
9	10	1	112	21·5	14	1	395
10	9	$1\frac{1}{4}$	126	22	18	$1\frac{3}{4}$	437
11	12	1	144	24	12	$1\frac{3}{4}$	465
9	9	$1\frac{1}{2}$	153				

N.B.—Tables showing the energy of projectiles are given in the "Treatise on the Construction of Ordnance."

* *Vide* the "Engineer," May 11, 1877 ("The 80-ton Gun").

The different materials used in the construction of armour-plates—*e.g.*, cast-iron, wrought-iron, and steel—will next be considered with respect to their comparative advantages or disadvantages for resisting the fire of heavy guns. Materials used for armour-plates.

There are two methods of destroying armour-plates, which may be employed according to circumstances—viz., *punching* and *racking*.

For *punching*, a high velocity is given to the projectile, of a comparatively small diameter, in order to drive it completely through the armour-plate, when the fragments of the projectile take effect on the guns, &c., behind it, and make a hole which if near the water-line of an iron-clad ship soon places it *hors de combat*. If, however, the armour-plate is so thick that it cannot be perforated, *racking* may be resorted to—*i.e.*, expending the energy of the projectile on cracking the armour and shaking it from its supports. This may be done most effectually with projectiles of comparatively large diameter and low velocities; the object being in this case not to penetrate but to break up the armour. It will be seen (p. 457) that wrought-iron plates yield to punching and resist racking, while steel plates of similar thickness yield to racking and resist punching.

The effect of projectiles on a cast-iron target is very destructive: the cast-iron cracks and flies, and in its ordinary condition it is not suitable for employment for defensive purposes. Chilled iron armour may be used in some places, where it is not likely to be subjected to continued bombardment, but the thickness required to resist fracture is much greater than that required by wrought-iron under similar circumstances. Cast-iron.

The effect produced by a projectile on a wrought-iron target is less destructive than upon cast-iron. Owing to the superior toughness and malleability of wrought-iron, there is not such a tendency to crack, and break up into fragments. A large number of experiments have, from time to time, been carried out at Shoeburyness in order to test the requisite thickness of wrought-iron plates to resist perforation.* Wrought-iron.

Iron plates are made either with the requisite thickness of iron in a single solid plate, or the thickness is made up of two or three iron plates interlined with wood. The former are called *solid plates*, the latter *laminated plates*.

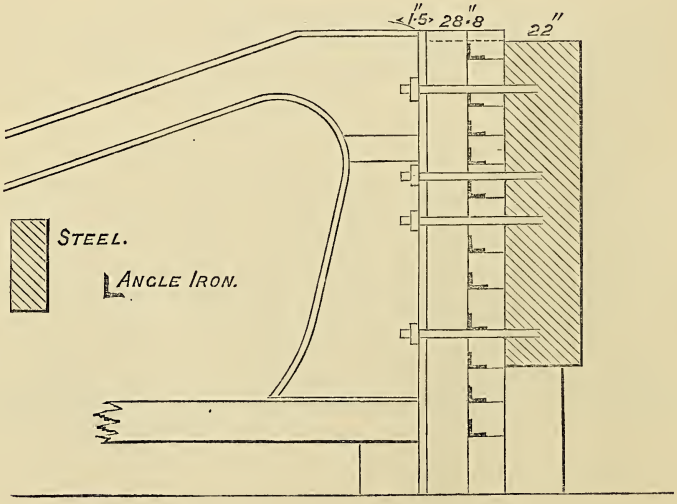
There are differences of opinion as to the relative merits of the two systems, when applied to the protection of ships or batteries. On the one hand, it appears that the laminated plate is more easily perforated than a solid plate of the same thickness. Colonel Inglis, R.E., considers that the resistance of armour-shields 7 ins. thick, composed of one, two, or three equal layers, are respectively as 100, 96, and 89; and that a single plate 17½ ins. thick is about equal to three 6½-in. plates separated by 5-in. layers of teak. On the other hand, the laminated plate system admits the employment of a wider plate; the plates themselves being more easily and soundly manufactured. In

* *Vide* "Extracts from the Proceedings of the Department of the Director of Artillery."

turret ships this is important, as armour-plates can be made of a breadth equal to the height of the turret, and through joints can thus be dispensed with, the bolting and securing of the structure is facilitated, and the absolute cost is less.

Steel. Armour-plates made of steel have some very important advantages which point to the advisability of employing steel instead of wrought-iron, either partially or entirely, for defensive purposes. Steel plates have a greater absolute tenacity, and more perfect homogeneity of structure than wrought-iron plates. They have also a greater resistance to penetration. This latter is of great importance, as it becomes possible by the use of steel armour to prevent ships' sides being punched or *perforated* by means of the heaviest gun yet made. There is, however, a great disadvantage which renders steel armour more susceptible of succumbing under the system of demolition by racking —*i.e.*, a crystalline structure which makes it liable to crack under relatively light blows; so that by repeated blows from medium guns the demolition of the steel plate is certain.

Experiments carried out by the Italian Government at Spezia in the autumn of 1876 with the 100-ton gun proved conclusively the value of the Schneider steel plates over wrought-iron plates of the same thickness. The Schneider steel target, which successfully resisted the 100-ton gun, striking with an energy of about 589 ft. tons per inch of circumference, consisted of a solid plate of soft hammered steel 22 ins. thick (*vide* figure), supported by two layers of wood backing—one vertical, the other horizontal. The wood backing was again supported by an iron plate 1·5 in. thick, and behind this again by the vertical frames of the ship, supported by the proper deck beams, those above being iron, and bent down to meet the ground at an acute angle; thus gaining the support which would be given by the other side of the



ship.* The bolts which passed through the backing to hold on the armour did not perforate the plate entirely; they were only screwed in about as far as the centre of the thickness of the steel. The first or horizontal layer of wood backing was further strengthened by angle-iron.

Another target of similar dimensions, so far as thickness of plate and backing are concerned, was made, having a front plate of 22 ins. of wrought-iron instead of steel, and the whole structure arranged in a similar manner to the steel target.

These two targets were subjected to the fire of 10-in. and 11-in. guns. The effect of these comparatively light guns on the Schneider steel target was to crack it. These cracks gradually extended, and the destructive effect of repeated shocks from these guns proved conclusively that the steel armour was quite unsuited for resistance to continued firing from these guns.

The wrought-iron target resisted the fire more successfully. Slight cracks occurred in the immediate proximity of the part struck; but these cracks did not spread, and there were no signs of cracks in other parts. The extreme penetration was 18 ins.; so that the wrought-iron target was quite strong enough to withstand the fire of 10 and 11-in. guns. Yet this target was completely perforated by the 100-ton gun, while the steel target was more successful in resisting the blow; so that the Committee of Italian officers at Spezia unanimously considered that a solid plate of Schneider steel is more advantageous than wrought-iron of similar thickness as armour-plating for ships' sides.†

Compound plates.

Experiments have since been made at Portsmouth with the view of combining the greater resistance to perforation offered by steel with the greater tenacity of wrought-iron. The advantage of wrought-iron as a material for armour-plates is that the effect of the blow is localised, and consequently answers better under the fire of ordinary heavy guns than steel. Plates thus made up of different metals are called *compound plates*. The object sought after is to have a hard steel surface welded on to soft wrought-iron, to prevent the steel from splitting.‡

A Wilson compound plate, consisting of a 5-in. hard-steel plate welded on to a 4-in. wrought-iron plate, was tested at Shoeburyness. The steel front was struck by a 7-in. Palliser shell, which broke up on impact, and penetrated to a depth of 3·2 ins., cracking the steel armour, but it did not extend to the iron. The penetration is much less than would have occurred in an ordinary wrought-iron plate of good quality; showing that on account of the breaking up of the projectile on the hard-steel plate, there was a considerable loss of work on the plate. The wrought-iron plate prevented the steel plate cracking so much as it would have done if the plate had wholly consisted of steel.

Other experiments have not been so satisfactory for the compound armour-plate; but it is probable that some combination of wrought-iron and steel will be employed as armour for ships' sides.

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* *Vide* letter from Special Correspondent of the "Times," dated Spezia, October 25, 1876.

† *Vide* p. 474, "Mittheilungen über Artillerie und Genie Wesen," 1877.

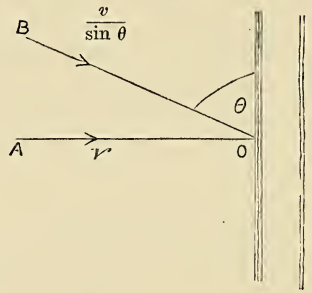
‡ *Vide* a paper in the "Proceedings of the Institution of Mechanical Engineers," "On the Construction of Armour to resist Shot and Shell," by Captain C. O. Browne, late R.A.

The form of head of projectile.

In order to investigate more fully the question of the penetration of armour-plates, it is necessary to consider the form of head and the material of the projectiles employed.

Several forms of head have been experimented with in this country —viz., flat, ogival, hemispherical, and conoidal. The ogival head struck with a radius of $1\frac{1}{2}$ diameters has been adopted for Palliser projectiles, as experiment has shown that this is the most suitable form for the penetration of armour-plates. An ogival head of two diameters has also given good results. The ogival head acts more as a wedge, and it consequently gives better results in penetration than the flat head, especially with thick solid plates. The flat head acts like a punch, driving the material of the armour-plate in front of it. This no doubt increases the resistance which a flat-headed projectile meets with in penetration.

The flat head is superior to the ogival, (1) when firing through water, (2) when firing at extreme angles of oblique fire. In the first case, a ship's side is more likely to be hit below the water-line by a flat-headed than by an ogival-headed projectile, since the ogival-headed projectile has a greater tendency to be deflected upwards by the water; in the second case, the ogival-headed projectile glances off the target where a flat-headed projectile would penetrate. A steel flat-headed projectile will penetrate at an angle of impact with the surface of the plate of about 30°, while the ogival-headed projectile of the best form will hardly penetrate at a less angle than about 40°.



Energy required to perforate a plate obliquely.

If v is the velocity required for a projectile to pierce an armour-plate with right-angled impact AO, its energy per inch of circumference

$$= \frac{Wv^2}{2g \,.\, \pi d}.$$

But if the projectile strikes obliquely, as BO, at an angle of impact θ, then, if it turns in on its point and perforates *normally*, it is readily seen that the velocity for perforation must be $\frac{v}{\sin\theta}$, and consequently the energy per inch of circumference for oblique perforation will be

$$\frac{Wv^2}{2g\pi d \,.\, \sin^2\theta};$$

so that in this case the number of foot tons per inch of circumference to perforate an armour-plate obliquely is found by dividing the

number of foot tons required for perforation by right-angled impact by the square of the sine of the angle of impact.

But if the projectile goes straight through the plate without turning in, the energy per inch of circumference for oblique perforation will be

$$\frac{Wv^2}{2g\pi d \sin\theta}.$$

This formula gives the best results for flat-headed projectiles and comparatively thin armour-plates.

Material of projectile.

Chilled iron, wrought-iron, and steel have been experimented on to ascertain their respective merits for materials to make projectiles for piercing armour-plates. Chilled iron has been adopted in this country, on account of its easier manipulation, its great hardness, and its comparative cheapness of production. The best material of projectile would be that which would neither break up on impact nor change its shape. Any change of shape means a loss of energy uselessly expended in heating the projectile; while if the projectile breaks up, it generally fails to impress all its energy on the target. Steel answers more to these requirements than either chilled or wrought-iron.

Experiments carried out at Shoeburyness with 9-in. projectiles with ogival heads and equal weights, made of steel or chilled iron by different manufacturers, and fired against an armour-plate of wrought-iron 12 ins. thick, have shown that steel is the best material for armour-piercing projectiles. The chilled iron shells break up on impact generally, while the steel shells rarely do so; and if they break up it is always in large pieces, and in some cases the head only separates from the body. The shells made of Whitworth steel give the best results; it was the only sample of steel which fairly pierced the plate and remained perfect without any sensible alteration in shape. The penetration with steel projectiles which neither break up nor sensibly alter their shape is greater than with ordinary chilled projectiles.

Armour-plates with intervals between them.

It has been found, when firing Palliser shell against armour-plates, that the destructive effect may be greatly modified by placing a thin armour-plate unbacked at a short distance in front of the armour-plate proper. The front armour-plate is of course easily penetrated, but in perforation the chilled shell is broken up, and the fragments have but little effect on the armour-plate in rear.

At Shoeburyness, on the 27th March, 1877, a Palliser shell was fired from the 38-ton gun at a 4-in. iron plate placed in front of another 10-in. plate at an interval of 4 ft. 7 ins. The shell passed through the 4-in. plate, making a hole 12·5 ins. in diameter, and breaking up in doing so. A quantity of it was found in a state of "splash" upon the face of the 10-in. plate. The 10-in. plate was comparatively little injured.

However, when firing steel projectiles which do not break up in perforating the thin armour-plate, this no longer holds good. A steel shell fired from a 9-in. gun completely pierced an 8-in. plate placed 4 ft. 6 ins. in rear of a 4-in. plate placed at an angle of incidence of 60°. It thus appears that the method of arrangement of armour-plates with intervals between them is useless for structures liable to

attack by steel projectiles; at the same time, it is a useful fact to remember in case of attack with chilled projectiles.*

The effect of common shell on armour-plates.

The penetration of common shell is considerable, although not to be compared with that of Palliser shell under similar conditions. The large bursting charge in the common shell renders it particularly destructive in cases where the armour-plate can be pierced. It may be fired with or without a percussion fuze. With the general service percussion fuze the burst takes place quicker than when no fuze is used.

The 10-in. M.L. gun, with battering charge and common shell, is capable of perforating a 5-in. iron unbacked armour-plate at 70 yds.

The effect of Palliser shells with wrought-iron points.

It has been ascertained by experiment that if a thin wrought-iron plate is placed in front of a steel plate, the whole structure may be perforated; while if the steel plate is placed in front of the wrought-iron plate, the projectile is broken up on impact and fails to perforate the target. In the latter case, the hard steel breaks up the projectile, and a part of the energy of the projectile is expended in breaking up before it can be impressed on the target; while in the former case, although the projectile may be broken up eventually, yet time is allowed, through the support afforded by the wrought-iron, for the projectile to impress nearly all its energy on the target.

On the same principle it was proposed by Captain English, R.E., to try the effect of a wrought-iron cap placed on the point of a Palliser shell, when firing against steel armour-plates. The wrought-iron cap was wrapped round the head of the shell, and secured by two steel pins fitting into the extractor-holes. The shell so capped was found to penetrate the steel armour, where the uncapped shell, under similar conditions, had broken up into small pieces and failed to penetrate.

Wood.

The effect of a projectile fired against wood depends on the nature of the wood, the direction of the blow with regard to the fibre of the wood, and the diameter of the projectile. Oak is the best wood to resist artillery fire, but its efficiency depends on the way in which the fibre of the wood is disposed. If the fibre is arranged perpendicularly to the general direction of fire (which is the best), there is a tendency in the wood to close up the hole completely when the projectile is of small calibre. With projectiles fired from siege and garrison guns the hole does not close up entirely, and large splinters are torn away from the back of the target.

If the wood is arranged so that the projectile strikes it along the fibre, it is seen to split and splinter even under the fire of field guns.

At about 900 yds. the 16-pr. gun may be expected to perforate 3 ft. 3 ins. of wood, and the 9-pr. gun at the same distance may be expected to perforate 1 ft. 10 ins. of wood.

Earth.

The effect of a projectile on earth can be more easily repaired than in the case of any other material. In general, the earth closes up the hole made; and if the earthwork is thick enough to resist complete penetration, the projectile buries itself in the earth with its point more or less turned round towards the direction from which it was fired.

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* For information on this subject, and on armour-plated targets generally, *vide* "Targets for the Trial of recent Heavy Ordnance," by Colonel T. Inglis, R.E., in the "Occasional Papers of the Royal Engineer Institute."

Penetration into Earth Targets (Sand and Clay).

Date and place of experiment.	Nature of target.	Ordnance.	Projectile.		Charge.	Range.	Striking velocity.	Angle of elevation.	Angle of descent.	Penetration.
			Nature.	Weight.						
				lbs.	lbs.	yds.	f.s.	° ′	° ′	ft. ins.
Tegel, 1870.....	parapet of loam	short 15^{cm} gun	common shell	61·1	3·3	1026	752	4 11	5 15	12 2
" 1872.....	"	15^{cm} steel gun	"	60·3	4·4	656	889	2 0	2 11	16 3
" 1870.....	parapet of sand	short 15^{cm} gun	"	61·1	3·3	1029	752	4 11	5 15	6 2·8
" 1872.....	"	15^{cm} hooped gun	live common shell	61·0	13·67	2734	935	4 45	6 45	16 3
" 1872...	traverse of sandy soil, thrown up 6 months before	12^{cm} bronze gun	common shell	32·2	2·3	1149	810	3 45	4 19	8 5
" 1876.....	parapet of sand	heavy field gun	"	15·4	3·3	437	1234	0 23	0 45	3 3·4
" 1876.....	"	light field gun	"	11·2	2·75	"	1286	0 19	0 37	3 3·4
Newhaven, 1863	clay	12-pr. B.L.R.	"	10·4	1·5	1060	987	—	—	4 0
"	"	40-pr. B.L.R.	shot	41·1	5·0	"	1014	—	—	14 9
"	"	7-in. B.L.	"	111·0	12·0	"	972	—	—	21 3
Tegel, 1863	sandy soil	21^{cm} mortar	common shell	176·0	3·3	1564	400	30 0	31 45	2 2
"	"	"	"	"	"	1488	402	60 0	62 7	2 4
"	"	"	"	"	7·7	3883	606	30 0	33 26	1 8
"	"	"	"	"	"	3609	623	60 0	64 15	4 5

N.B.—The German experiments are taken from the "Handbook for Prussian Artillery Officers," translated by Major C. H. Fairfax Ellis, R.A.

Masonry.

The effect of a projectile on masonry is to make a conical hole on the surface, and then a clean cut as far as it will penetrate. The masonry in front is shattered, and pieces fly back some considerable distance towards the breaching battery. The depth of penetration varies with the shape and material of the projectile.

Penetration into Masonry (Brickwork).

Date and place of experiment	Nature of target.	Ordnance.	Projectile.			Charge.	Range.	Elevation.	Angle of incidence,	Angle of descent.	Striking velocity.	Energy on impact.	Size of crater.			Amount of masonry displaced.	Masonry displaced		Remarks.
			Weight.	Live or plugged.	Fuze.								Depth.	Breadth.	Height.		per ft. ton of energy.	per lb. of projectile.	
			lbs.			lbs.	yds.	° ′	° ′	° ′	f.s.	f.t.	ins.	ins.	ins.	cub.in.	ins.	ins.	
Graudenz, 1873.	strong brickwork	short 15cm gun	61·2	Live com. shl.	service	3·3	1488	5 37	90 0	7 34	732	265	17·3	55·1	39·6	10983	41	183	
"	very hard brickwork	"	"	"	delayed action	3·3	96	—	74 0 to 82 0	4 3 to 5 0	822	291	25·2	47·5	43·5	14975	51	249	
"	"	"	"	"	service	3·3	96	—	"	"	822	291	27·5	39·6	43·6	13636	47	227	
Stettin, 1868.	good brickwork	15cm gun	"	plugged com. shl.	—	4·4	110	—	66 15	14 0	980	414	39·6	37·1	18·5	8291	20	138	
"	"	"	"	"	—	5·0	110	—	68 30	14 0	1038	464	39·0	37·1	33·9	12925	28	215	
"	"	"	60·3	filled com. shl.	service	4·4	110	—	74 31	14 0	939	366	27·6	47·4	39·5	14598	40	243	
Graudenz, 1873.	very hard brickwork	15cm hooped gun	61·1	plugged com. shl.	—	8·6	186	—	64 0 to 70 0	3 0 to 4 0	1148	568	35·8	33·5	39·6	12988	23	216	Shell remained in hole.
"	"	"	"	"	—	10·8	"	—	"	"	1312	725	39·5	32·3	39·6	13948	19	230	"
"	"	"	"	"	—	13·1	"	—	"	"	1476	938	39·6	47·2	43·5	22940	24	382	Shell broke up on impact.
"	"	"	"	"	—	13·7	"	—	"	"	1525	1000	37·4	43·3	39·4	16736	17	278	"
"	"	"	"	live shell	delayed action	8·6	"	—	"	"	1148	568	39·6	59·1	39·4	25961	46	432	
"	"	"	"	"	service	8·6	"	—	"	"	1148	568	39·6	43·4	51·2	24528	45	409	
"	"	"	"	"	none	8·6	"	—	"	"	1148	568	37·0	67·1	63·0	42137	74	702	Shell exploded in the wall.
"	"	"	"	"	delayed action	10·8	"	—	"	"	1312	725	39·5	55·2	47·4	28575	39	476	
"	"	"	"	"	service	10·8	"	—	"	"	1312	725	39·5	55·1	51·3	30139	41	502	
"	"	"	"	"	delayed action	13·1	"	—	"	"	1476	938	36·6	59·0	59·2	33427	35	557	
"	"	"	"	"	service	13·1	"	—	"	"	1476	938	33·9	74·8	59·3	40887	43	681	
"	"	"	"	"	delayed action	13·7	"	—	"	"	1525	1000	43·3	71·1	63·2	54303	54	905	
"	"	"	"	"	service	13·7	"	—	"	"	1525	1000	39·6	75·0	59·1	50391	50	839	
"	"	"	"	"	none	13·7	"	—	"	"	1525	1000	26·8	55·3	55·1	31790	32	529	Shell exploded in the wall.

Vide "Handbook for Prussian Artillery Officers," translated by Major Ellis, R.A.

With concrete the surface is more broken up than with masonry. Concrete generally breaks up in layers, but it is superior to masonry in resisting penetration. Concrete.

The following table gives the penetration into brickwork and concrete, from experiments carried out at Eastbourne in 1876 :—

Material of target.	Nature of ordnance.	Projectile.		Charge.	Range.	Penetration.
		Nature.	Weight.			
			lbs.	lbs.	yds.	
Brickwork	64-pr. M.L.R.	common shell	64	10	1000	3 ft. 2 ins. to 5 ft.
"	"	battering shell	89	12	"	Perforated 7 ft. of wall.
Concrete	"	"	"	10	100	4 ft. 8 ins.
"	"	common shell	64	"	"	2 ft. 6 ins.
"	"	"	"	12	1000	4 ft.
Granite and Portland cement concrete	12·5-in. M.L.R.	Palliser shell	822	130	70	Perforated 11 ft. and destroyed the wall.

(To be continued.)

[*Extract from the Miscellaneous Works of Mr. John Greaves (Savillian), Professor of Astronomy in the University of Oxford.*]

AN ACCOUNT BY MR. J. GREAVES OF SOME EXPERIMENTS FOR TRYING THE FORCE OF GREAT GUNS.

COMMUNICATED BY

MAJOR TRACEY, R.A.

1651, March 18,

Woolwich.

At 200 yds. distance from the platform for great ordnance there were raised 3 butts, one behind another. The space between the 1st and 2nd butt was 14 yds., between the 2nd and 3rd 8.

The thickness of each butt was 19 ins.; whereof 13 was of beams of massy oak fastened into the ground, and set so close that they touched each other.

On each side were planks of oak, 3 ins. a piece in thickness; and these were joined close, and fastened on both sides with iron bolts and strong pins of wood; and on the back, at the ends, and on the middle there were three braces of elm, a foot in breadth, and five inches in thickness.

The 1st experiment was with an iron demi-cannon of 3500 lbs. weight, the bullet 32 lbs. of iron, the powder 10 lbs., which pierced thro' the two first butts, and struck in the third, so as the ball was almost quite within, but the timber not shivered small, nor scarce split. The butts, being touched by me, felt quite warm.

The like execution was done when it was charged with 9 lbs., as also when with 8 lbs. of powder. This demi-cannon was with a cylinder bore.

The 2nd experiment was with a demi-cannon having a taper bore, and being 3600 lbs. in weight, and 4 ins. longer than the former, the iron bullet 32 lbs., and the powder 7 lbs., which in three trials seemed to have the same force with the first. One of the shots, piercing through the 2nd butt and lighting near the edge of the middle butt of elm, tore it; but by the yielding of it, the bullet glanced aside off the 3rd butt, and entered into the earth.

The 3rd experiment was with a whole culverin in brass, 5300 lbs. in weight, 11 ft. 1 in. in length, with a taper bore. The iron bullet was 18 lbs. in weight; the powder in the 1st trial 10 lbs., in the 2nd 9 lbs., in the 3rd 8 lbs., which last proportion did the best execution, and passed thro' the 2 first butts, entering gently into the 3rd, which the former two did touch but did not enter.

The 4th experiment was with a whole culverin in brass, made at Amsterdam for the French, with this mark, 3580, being 10 ft. long, and not very thick in the breech.

The 1st shot, with 9 lbs. of powder, 18-lb. bullet of iron, passed thro' the 3 butts, and entered one foot into the ground. It passed by the joints of the timber, 2 planks having been bent down before.

The 2nd shot, with 8 lbs. of powder, passed thro' 2 butts, and grazed between them.

The 3rd, with 8 lbs., passed the two butts, and 7 ins. into the 3rd; but the 1st butt was much shattered before where it entered.

The 4th shot passed, with 8 lbs. of powder, 2 butts, and in both butts passed thro' the midst of a massy strong beam below that had not been battered.

The 5th experiment was with an iron demi-culverin, having a 9-lb. bullet in iron, and 4 lbs. of powder. This passed one butt which was torn before, and entered the 2nd.

This half-culverin was shot eight times, as fast as they could charge it with powder and the iron bullett, and yet was but scarce lukewarm at the breech, a little more in the midst, most at the muzzle, and this last scarce so hot as my hand, and yet the gunners in charging her wet not at all the scoop or spunge.

The 6th experiment was with a brass demi-culverin. The breech of her was $13\frac{1}{8}$ ins., tried with a caliper compass, the mouth $2\frac{5}{8}$ ins. The first shot, with 4 lbs. of powder, 9-lb. iron bullet, passed two butts; the 2nd shot, with 3 lbs. of powder, passed almost two butts.

This proved to be the best shot, because the timbers were strongest.

FINIS.

THE

WAR BETWEEN RUSSIA AND TURKEY

IN ASIA MINOR, 1877.

Translated from "Löbell's Jahresberichte" (by permission of Col. von Löbell),

BY

LIEUT. J. M. GRIERSON, R.A.

[PART II.]

THE result of the First Period of Operations was that the energetic but badly concerted offensive movement which the Russian army had undertaken with insufficient forces was turned into a pure defensive, and all its efforts were now directed to the prevention of an invasion of Russian territory by a victorious enemy. The forces available for this purpose seemed more than sufficient in the Rion Column, as it was strongly entrenched in an excellent position, and its communications were secured by the Ingur Column, which had troops enough for this purpose. The Ardahan detachment had no enemy in its front. The Alexandropol Column, although numerically weak, had a strong *point d'appui* in the fortress of Alexandropol, and its positions on the Lower Kars Tchai, and on the Arpa Tchai were very strong. The Erivan Column alone, in its isolated condition, was not strong enough to resist the invasion of the Government by Ismail Hakki Pasha, so all disposable troops had to be hurried up to its support. After the left wing had been sufficiently strengthened by withdrawing troops from the other columns and bringing up reinforcements from the interior up till the end of August, all the reinforcements from Europe, the last échelon of which arrived towards the end of September, were used to strengthen the centre.

In Notes I. and II. are given the details of the reinforcements and the new formation of the columns.

(*a*) RION COLUMN.

The operations in Northern Lazistan during the Second Period are of quite a secondary character, as the peculiar position of the Rion Column prevented its undertaking any important advance. After his corps had

been reduced to about half its original strength, General Oklobjio had to remain purely on the defensive, and confine himself to repelling the badly concerted attacks of the enemy. He therefore remained in the fortified camp of Mukha Estate, secured by strong outposts. On the 13th August the right flank of the outpost-line was attacked, but it succeeded in retaining its position with a loss of 61 men. On the 24th of the same month Dervish Pasha attacked the outposts all along the front; but the attacks of the infantry, covered by the fire of the artillery, all failed against the excellent position of the Russians, and he had to retire to his camp with considerable loss. On the 21st September, Dervish Pasha again tried to push on to Fort St. Nicholas, under cover of a combined bombardment of the camp of Mukha Estate from the fleet and from his artillery, but signally failed.

The powerful blow which was dealt on the Turkish power at Kars in the middle of October made itself felt also in this quarter; Dervish Pasha retired to Erzeroum in the beginning of November with 7000 men, but left sufficient troops in his advanced position on the Adkova to totally repulse an attack on it by the Russians on the 7th of November. The capture of Kars worked a change in the whole aspect of affairs; for as the main body of the Russian troops was thus set free, Dervish, fearing that a portion of them might advance down the Djorokh Valley, by Ardahan and Ardanutsch on Batoum, withdrew the main body of his troops from the Khotzubani position to Batoum on the 27th November, leaving only a weak rear guard in it, which was attacked on the 28th by Colonel Kasbek. The Turks, after a very feeble resistance, fled to behind the Kintrischi, leaving the camp for 10,000 men with immense quantities of stores to fall into the hands of the Russians, who at once occupied it, and did not advance further in the whole course of the campaign. An unsuccessful attempt by the steamer "Constantine" to blow up a Turkish monitor by torpedoes in the roadstead of Batoum, on the 28th December, closed the hostilities of the campaign in this district.

(*b*) Akhaltzikh Column.

[See Note II.]

(*c*) Alexandropol Column.

[This will be treated of after (*d*) for reasons explained therein.]

(*d*) Erivan Column.

From the Surp Owhanes-Diadin-Bayazid road, three roads run northwards over the Tchangil Mountains into the Karasu Valley, in the S.W. corner of which lies Kulpi on the Alexandropol road, and in the N.E., Erivan. The centre road ascends from Diadin *viâ* Misun and the Caravan Pass on the frontier to Osma, and turning to the east at Tcharutzi runs on 50 kils. farther to Erivan; a branch leaves this road N.E. of Osma and runs by Alakogaski and Chalfaly to Igdyr, and thence (40 kils.) to Erivan. The eastern road runs from Kurabulach,

crossing the frontier at Orgoff, to Igdyr; so that the latter is an important road junction at which an advance on Erivan by the centre or eastern roads can be met and checked. After the relief of the garrison of Bayazid, Tergukasoff, pressed back by the superior numbers of Ismail Pacha, to whom he could offer no resistance simultaneously in the three passes, had retired his main body to Igdyr, and there awaited reinforcements in a defensive position. Before these had arrived in any strength, Ismail threw forward a strong advanced guard over the Caravan Pass to Alakogaski, on the 5th August, and in vain struggled to throw the Russians back on Igdyr from Chalfaly; the main body (40 battalions) had remained at Misun on their own side of the frontier, and while Ismail detained the Russians by his advanced guard which remained in Alakogaski, he made a demonstration with a small flank-detachment towards the western pass at Abasgul, and advanced his main body by the centre road through Osma against the Russian right in Tcharutzi. The head of this column was repulsed on the 20th August at Guludji, but the advanced guard succeeded in pressing forward to near Igdyr, from which they were driven back to Tcharutzi on the 24th by Colonel Ismailoff. Ismail now joined his former advanced guard to his main column, and advanced on the 27th in three columns on Tcharutzi and Chalfaly, but failed to seize either of those positions. There then ensued a pause till the middle of September, during which time Tergukasoff was continually receiving reinforcements, but he still was not strong enough to assume the offensive. On the 19th September Ismail again directed attacks on the same positions, which met with a much more powerful resistance than before, although the Turks themselves were much stronger. On the 21st he repeated his attacks, and at last, on the 27th, tried to turn the Russian right by an attack in great force on Tcharutzi. The 74th, 76th, and 154th Regiments not only repulsed this attack in a most brilliant manner, but also assumed the offensive, and drove the Turks so far back from this oft-endangered position that no further attack on it was attempted. The heaviest Russian loss during all these combats was that of this last day; it was only 176 men, however, so from this figure the tactical importance of the former combats may be judged. From this time Ismail's determined attacks ceased, as in the beginning of October he had to send about half of his troops to Mukhtar Pasha. Lastly, on the 14th October, Ismail made a slight attack on Chalfaly, and then, influenced by Mukhtar's defeat at Kars, by which his own long line of retreat appeared endangered, retired, and begun his retreat on the 18th October, reaching Gerger (10 kils. east of Karakilissa) on the 24th, on which day Tergukasoff occupied Diadin, two days' march from it. Ismail availed himself of his two days' start in a most energetic manner, got over 120 kils. in the next three days, and on the 27th, on the last day on which it was possible, reached the bridge over the Aras at Köpriköi, and there joined Mukhtar's rear guard. On the 28th Tergukasoff's cavalry advanced guard, which had pursued Ismail in vain, and had got over 180 kils. in four days, joined Heimann's advanced guard, which had advanced from Ardost, at Köpriköi. From this day the Erivan Column was put under the direct command of Loris-Melikoff, and was

absorbed in it; its further operations will therefore be treated of in the next part.

(c) Alexandropol Column.

The position taken up by the outposts of both sides at the end of the First Period of Operations remained unaltered till the middle of August, and neither army gave up its attitude of simple observation. Loris-Melikoff, working on interior lines, kept his main body, which had been reinforced by the whole Ardahan detachment, in the entrenched camp of Kuruk Dara, so that it was in a good position for defending both the roads to Kars. Mukhtar had indeed a longer line to defend, but along it were many almost impregnable positions, on plateaus with steep rocky slopes. His left at Khalif Oghlu and on the Little Yagni commanded the northern road from Alexandropol to Kars; next to this was the position of the Great Yagni (Yagni Tepe), between which and the Avlijar ran the southern road to Kars. The broad space between the Avlijar and the bend to the west of the Arpa Tchai at Megaspert was filled up by the mighty Aladja Dagh plateau. Here his right flank rested on the Russian frontier, so that an advance into Turkey seemed everywhere barred. In front of the centre of the line were two strong advanced positions, the ridges at Hadji Vali and Subotan, and in front of these still the Kizil Tepe; behind the centre were, as second line, the positions of Vezinkoi, Tchift Tepe, and Orluk Dagh. The front of the whole position was about 30 kils., the depth 25, including the second line.

Mukhtar's position was in every direction and for all purposes stronger and more suitable than that of his opponent, and yet he lost a golden opportunity for striking a blow with his right wing, when as yet the numerical superiority was on his side. On the 8th of August hostilities began simultaneously on both sides; from the Russian right a strong reconnaissance was pushed forward on the northern road towards Hadji Vali, while the Russian outposts at Kaidikler, near the southern road, were attacked by the Turkish centre. Both advances were unimportant. On the 18th August Loris-Melikoff felt himself strong enough to undertake a demonstration along his whole front, in order to force his opponent to deploy his forces. The preliminary advance was made against the Turkish left wing, while on the other parts of the front there was only a lively cannonade. The object of the demonstration was completely gained, for it was easily seen that Mukhtar's centre was so strongly held that a real attack with the forces at present at the disposal of the Russian General would have no chance of success, and that therefore an offensive movement on a large scale would have to be put off till the arrival of all the reinforcements, which could not be expected before the end of September. The loss on the 18th August was about 400 men on each side.

In the night from the 19th to the 20th August, Major-General Prince Tchavtchavatze advanced on the southern road with 12 sotnias and a battery against the camp of the cavalry outposts of the Turkish

centre in front of Avlijar at Bulanak, surprised it, and returned into camp with trifling loss.

In the hope of driving back the Russian right wing by an overwhelming attack, Mukhtar advanced on both roads against the Kuruk Dara and Karajal positions on the 25th August—in fact, ran his head against the strongest part of the Russian line. After twelve hours' hard fighting the attack was repulsed. The Russian loss was a good deal over 1000 men, while that of the Turks is said to have been only 1200. At any rate the result of the day's fighting, the details of which are not completely known, was that Mukhtar seized and held the strong advanced position of the Kizil Tepe, which was only about 4 kils. from the Russian outpost line, and therefore unpleasantly near; his main body remained at Subotan and Hadji Vali, but the positions of his right and left wings remained unchanged. On the 26th August, therefore, he occupied a wedge-like position, the point of which was strongly held.

The entire month of September passed away without any noteworthy occurrences. Mukhtar remained almost totally inactive in his positions, in the expectation that Ismail Pasha would be able to push up the left bank of the Arpa Tchai, by Kulpi, and then begin a concerted attack on the Russian positions. On the 6th and 13th September Loris-Melikoff made two minor reconnaissances, the last against the extreme left of the Turkish army, without learning anything by them except that Mukhtar had made no change in his dispositions.

By the 26th September the last reinforcements had entered the Russian camp, and as the approaching winter would soon make operations very difficult, Loris-Melikoff began his preparations for an energetic offensive, the supreme direction of which was in the hands of the Grand Duke Michael. Mukhtar's line, the separate positions of which were immensely strong, had, however, one weak point, and it was that since the occupation of the Kizil Tepe he had two fronts to occupy—one facing north, the left of which rested on the Little Yagni, the other fronting east, with its right in Megaspert, while the inner flanks of both rested on the Kizil Tepe. The length of each front was about 20 kils. If one of those fronts were attacked and the Russians succeeded in driving in the outer wing, the Turkish reserves, placed behind both faces, and the common line of retreat would be endangered.

The Russians decided to attack Mukhtar's north front, as the approach to the other was very difficult; but a turning movement on the Turkish left could not be performed because it was covered by the fortress of Kars, which was only 15 kils. off. They were therefore compelled to direct the main attack on the inner part of the Turkish left and the positions near it, while a demonstration was to be made before the right wing and the east front, to draw off the Turkish reserves. On these general principles the attack of the 2nd October was arranged. The extreme right wing, under General Roop, failed, after repeated attacks, to take the Little Yagni, as 13 battalions had arrived from Kars to join in its defence, while General Scheremetieff succeeded after two hours' fighting in taking and holding the Great

Yagni. Schack's demonstration in front of Hadji Vali did not prevent strong Turkish reserves from being brought up to prevent an advance of the Russians from the Great Yagni. The distant demonstration made by Major-General Schelkovnikoff on the Turkish east front, although well carried out, had no influence on the issue of the day. After the battle the Russians bivouacked on the ground they had won and remained there next day. On the evening of the 3rd October Mukhtar Pasha attempted an attack on the Russian left from Hadji Vali; but though he failed, the massing of Turkish troops on that evening on the Kizil Tepe seemed to endanger so much the Russian lines of retreat, that Scheremetieff had to abandon the Great Yagni, in order not to be cut off in this advanced position. Both the other columns retired on account of the scarcity of water on the morning of the 4th into their former positions, and twice repulsed feeble attacks of the Turks. The Russian loss on the 2nd was above 3500 men, that of the other two days 500; the Turkish loss is unknown.

The success of the Russian attack had shown Mukhtar the weak point of his extended and disjointed front; so that on the 9th October he felt himself compelled not only to evacuate the Kizil Tepe and withdraw to his former positions, but also to send to Ismail Pasha asking him to hurry up all the troops which could be spared to reinforce his army, to compensate for his evident numerical inferiority. He entrenched as strongly as possible, as far as the rocky ground permitted, the positions on the Avlijar, the Little Yagni, and the Aladja Dagh, also the Inach Tepe group as a first line, but left the great Yagni, which was a little out of the line, completely unoccupied. As second line, on an average 7 kils. from the first, he fortified the heights of Vezinkoi, the Tchift Tepe, Orluk Tepe, Schatir Ogli, and Bazardjik. It must be remarked that Kars, only 15 kils. from the Little Yagni and Vezinkoi, formed an important support for the left flank and centre of the position. The strength of Mukhtar's army is not known with certainty, but 50 weak battalions cannot be far from the true figure.

The Grand Duke Michael recognised that this formidable position could only be taken by a wide turning movement round its right flank, and a combined attack on its front and rear. General Lazareff, therefore, with the 40th Infantry Division, 75th Regiment, 4th Rifle Battn., 16th Dragoons, 1st and 2nd Volga, 3rd Daghestan, and Alexandropol Cossack Regiments, 40th Artillery Brigade, 6/19th and ¼ 6/39th Artillery Brigade, 1st Terek and 2nd Don Cossack Battery, and ½ 3rd Sapper Battalion, began his march from Bairaktar and Ozuglu on the 9th and 10th, crossed the Arpa Tchai, marched 30 kils. southwards along its Russian bank, and at the frontier fort of Kambinsk, where he picked up two battalions of the 153rd and the 2nd Kisliaro Cossack Regiment, crossed again into Turkish territory, and advanced westwards to Digor, which he reached on the 12th. There he united with Major-General Zitovitch, who had been detached from Tergukasoff's corps with the 154th Regiment, two sotnias of Uman Cossacks, and the 5/39th Artillery Brigade, and had advanced by Hadji Bairan. Digor lies 14 kils. behind the extreme right wing of the Aladja position, and 13 kils. on the right flank of Bazardjik. Lazareff's troops now mustered 23½ battalions, 28 squadrons, and 10¼ batteries (82 guns).

On the 13th he halted in Digor, which was fortified and held by three battalions as a *point d'appui*.

After receiving the news of Lazareff's arrival, the Grand Duke began on the 13th to prepare his frontal attack by occupying and fortifying the evacuated Great Yagni. An attempt of the enemy to frustrate this was repulsed.

Lazareff now advanced on the 14th October against the right flank of the Turkish reserves in Bazardjik and on the heights of Schatir Oghlu, and although those positions were defended by at least 10 battalions, the 5 battalions of the Russian advanced guard (154th Regiment and 4th Rifle Battalion), supported by a flank attack of the 16th Dragoons, succeeded in driving the Turks out of them. After a preparatory artillery combat by 2¼ batteries, Lazareff, late in the afternoon, stormed the positions lying north of those and commanding them —viz., the southern part of the Orluk Dagh—so that by evening he stood in rear of the enemy's centre, with the former position of the reserves of the Turkish right in his possession. This day, the Turks, although under Mukhtar in person, fought badly, and their retreat was accomplished in great disorder.

For the frontal attack which was to meet Lazareff's at right angles at Vezinkoi, the troops were divided as follows:—

Left Wing.

Major-General Kuzminski.

152nd and 156th Regiments.
2nd Daghestan, Tschetchna, and Tiflis Irregular Cavalry.
1st Grenadier Artillery Bde.
½ 6/19th Artillery Brigade.
3, ½ 5/38th Artillery Brigade.

Between Kerkahn and Tainalik.

2 siege guns in position on Kizil Tepe.

8 battns., 24 squads., 3 batts.

Right Wing.

General Heimann.

Caucasus Grenadier Division and Artillery Brigade.
1st Brigade in Hadji Vali.
2nd Brigade on Great Yagni.

Reserve.

Major-General Solovieff.

2nd Grenadier Regiment.
3 Battalions 151st Regiment.
1st Rifle Battalion.
15th Dragoons, 6th Orenburg Cossacks.
2/1st Grenadier Artillery Bde.
2/21st Artillery Brigade.
3, 4/39th Artillery Brigade.
5th Kuban Battery.
16 siege guns.
1st Sapper Battn. (in Subotan).

On hill of Hadji Vali, 3 siege guns in position.

24 battns., 8 squads., 11 batts.

Right Wing Detachment.

Major-General Grabbe.

3rd Grenadier Regiment.
3 sotnias 7th Orenburg Cossacks.
3/1st Grenadier Artillery Brigade.

On Kabach Tepe.

Right Flank Detachment.

Maj.-Gen. Prince Wittgenstein.

Kuban Cossacks.
2nd Vladikavkas Cossacks.
2/3 Eisk Cossacks.

In Engikioi, on the Kars Tchai, to protect extreme right.

General Reserve.

Major-General Dehn.

1st and 4th Grenadiers.
17th Dragoons.
2nd Astrakhan Cossacks.
2, 5, 6/1st Grenadier Artillery Brigade.
2nd Kuban, 14th Don Battery.
½ 3rd Sapper Battalion.

West of Pulvaran.

6½ battns., 8 squads., 5 batts.

General Roop commanded the left wing and reserve, and Loris-Melikoff the whole of the above-mentioned troops. The Grand Duke Michael commanded the whole Alexandropol Column, including Lazareff's detachment.

6.30 a.m. was named as the time for the commencement of the operations.

Right Wing.—The 2nd Caucasus Grenadier Brigade (Schack) on the Great Yagni, with its artillery, covered the right from attacks from Kars and the Little Yagni. At 9 a.m. eight batteries were in position against the Avlijar, which after a hard fight had advanced to within the range of case by 10 a.m. On the right the 13th Grenadiers, in the centre the 151st Regiment, and on the left the 14th Grenadiers, now formed for the attack. Before the advance began, seven Turkish battalions made a determined attack from Vezinkoi on the 1/13th Grenadiers, on the right flank; the battalion, however, was supported by the 1st Rifle and 1st Sapper Battalions, and by the help of the guns on the Little Yagni, the attack was repulsed, and the troops immediately advanced (12 noon) to storm the position. The Turks were driven back on Orluk and Vezinkoi, leaving three guns in the hands of the Russians. Heimann followed them up with a battalion of the 3rd (sent by Grabbe) and the 4th Grenadier Regiment.

Lazareff's Column.—Before Heimann advanced to storm the Vezinkoi Heights, Lazareff, from the south, had captured them with the 154th, two battalions of the 153rd, and two of the 75th Regiment, so that both columns joined hands here. The Turks retired in wild confusion to the village of Vezinkoi, and many prisoners were made by the 16th Dragoons. Closely following the dragoons, the 154th Regiment stormed the village of Vezinkoi, so that the 13th and 14th Grenadiers were enabled to surround the heights of Tchift Tepe, while Lazareff sent back a part of his troops to push up closer to the rear slopes of the Aladja Dagh, which General Roop had not yet captured. The latter had not at first been able to make a frontal attack with his infantry; but after he had brought up a sufficiently powerful mass of artillery, and prepared the way by its fire, he sent forward the 1st Grenadiers on the right, the 156th in the centre, and the 152nd on the left, while his cavalry tried to cut off the retreat of the enemy. The Turks did not wait for the attack; part fled towards the southern slopes and part surrendered, but those who fled from Roop's troops fell into the hands of those of Heimann and Lazareff, who had gradually narrowed the circle round the Tchift Tepe and northern Orluk positions. The Turkish retreat from Vezinkoi to Kars was barred by Loris-Melikoff's cavalry, and that from the Little Yagni by Prince Tcherbatoff, while from the front Prince Wittgenstein pressed on. Those Turks who had not succeeded in escaping through the gaps in the Russian lines towards the south and south-west, now saw themselves surrounded on all sides, so at first the Turkish leaders surrendered to the Russian troops standing opposite them, and finally, in the evening, Omer Pasha, the Commander-in-Chief, capitulated.

Seven Pashas, with seven thousand men, capitulated, while Mukhtar

Pasha hastily retired from Kars on the road he knew so well towards the Soghanli Dagh, with eight battalions, to rally as many stragglers as possible.

The Russian loss on both days (1441 men) may be considered small, and shows in a striking manner the tactical superiority of the Russians and the feebleness of the Turkish defence.

The defeat of the Turks on the 14th and 15th October was the turning point of the campaign in Armenia, and its consequences were felt even on the European theatre of war, as 10,000 men, destined for the latter, were embarked at Constantinople for Erzeroum (*viâ* Trebizond) from the 16th to the 19th October. Its direct influence on both the other lines of operation in Armenia has already been traced in the preceding chapters.

The Russian operations had now two distinct objects—the pursuit of Mukhtar Pasha, and the endeavour to hinder his junction with Ismail's troops, and the blockade of Kars. The siege army was placed under General Lazareff, and consisted of the 1st Grenadier and the 40th Infantry Divisions, the 2nd Brigades of the 19th and 38th Divisions, the 155th Regiment, 1st and 4th Rifle Battalions, the 15th, half of the 16th, and half of the 17th Dragoons, the Cossack Division, the 1st and 2nd Volga, 2nd Astrakhan, the 2nd Kisiliaro and the Poltava Cossacks, the 3rd Daghestan and the Akhaltzikh Cavalry Regiments, the 1st Grenadier Artillery Brigade, the 1st, 2nd, 5th, and 6th/40th, 6th/19th, 3rd and 5th/38th, 3rd, 4th, and 6th/39th Artillery Brigades, the 2nd and 5th Kuban and 13th and 14th Don Horse Batteries, and the 3rd Sapper Battalion. All the other troops of the Alexandropol Column (see Note II.) were placed under the command of General Heimann for further operations against Mukhtar Pasha, and started on the 20th for Tikhma. Mukhtar had reached the Soghanli Dagh on the 20th, and there took up a defensive position, to cover Ismail's passage of the Aras at Köpriköi; he held it till the 27th, although his outposts had been driven in by General Heimann. The Turkish retreat had now to be carried out as quickly as possible, as on the 28th October the advanced guards of Heimann's and Tergukasoff's columns had united at Köpriköi, and on the 29th they succeeded in surprising the Turkish rear guard at Kurudjuk. Heimann halted at Kurudjuk to wait for the main body of Tergukasoff's column, the last échelon of which arrived on the 3rd November.

Mukhtar Pasha thus gained time to fortify the last defensive position before Erzeroum, the Deve-Boyoun on the north, and the Palandoken Dagh on the south of the road, and to occupy it with about 60 battalions, 8 squadrons, and 50 guns, the greater part of which belonged to Ismail's army; a few reinforcements from Europe, but none from Batoum, had reached him. The centre of the position was its weakest part; the road, which ran between the two ridges, was only defended by a small fortified camp, while both the elevated flanks of the position, strong by nature, had been heavily entrenched. The position of the Turkish right wing, on the outer flank of which were the villages of Gildji and Topadjik, was almost impregnable; but its one fault was that the only line of retreat from it lay behind the weak centre, so that if the Russians broke through here, the Turkish right would have to

retire over the snow-covered summits of the Palandoken Dagh. The position of the left wing, which indirectly protected the high road, was secured in front by the plateau of Uzun Achmet, but its left could be turned by a deep ravine. This ravine was protected by the advanced Tschoban Hill, but if this fell into the hands of the Russians, the plateau of Uzun Achmet could be turned and taken, and so the command of the high road and the line of retreat of the right and centre lost.

After those weak points had been observed by a reconnaissance of all the commanders of regiments on the 2nd November, the following dispositions were made for an attack on the 4th:—

Left Wing.

Maj.-Gen. Schack.

2nd Brigade Caucasus Grenadier Division.
1 sapper company.

Left Centre and Reserve.

Maj.-Gen. Avinoff.

1st Brigade Caucasus Grenadier Division.

Cavalry Division.

Major-General Prince Amilochvaroff.

3 regiments, 1 battery.

High road to Erzeroum.

Right Wing.

Lieut.-Colonel Prince Admiradjiboff.

153rd Regiment.
156th Regiment.
3rd Rifle Battalion.

Right Centre and Reserve.

Maj.-Gen. Bronevski.

1st Brigade, 19th Division.
150th Regiment.
3 batteries.

Cavalry Division.

Major-General Kebalai Khan.

3–4 Regiments, 1 battery.

3000 mètres from the hostile lines, in position,

48 guns. | 30 guns.

All the other troops remained in camp at Kurudjuk.

Right Wing.—At 9.45 a.m. the Turkish artillery opened fire against this column, which was in the act of forming up; the fire was returned by the Russians. The 3rd and 4th Battalions, 73rd Regiment, now occupied the first range of the Tschoban Heights, driving two battalions with five guns back from it to the second range, which was held by four battalions with seven guns. Three Russian batteries now came into action on the captured position to prepare for a second attack, and the grand artillery mass advanced to 1200 mètres trom the Turkish position.

Left Wing.—After a long preparatory cannonade, at 12 noon two companies of the 16th Grenadiers and some sappers seized the village of Gilji and the ravine in front of it, but an attempt made by Schack to push forward his left wing failed. At 2 p.m. Ismail Pasha threw forward three battalions against the ravine of Gilji, and eight battalions with a regiment of cavalry against Schack's left wing, formed by the 15th Grenadiers. Both attacks were repulsed, as also a third made at 4 p.m. by eight battalions against Gilji, to hold which the whole of the 16th Grenadiers was brought up. The 14th Grenadiers were sent up from the reserve, but did not come under fire, as Schack remained in the positions he had conquered till darkness.

Right Wing.—Strengthened by a battalion of the 73rd and one of the

150th from the reserve, which he placed in rear of his left flank, Admiradjiboff advanced at 4 p.m. to the attack; the second range of the Tchoban Heights was stormed by a direct attack, and the enemy's attention drawn to their front, while a battalion from the right flank pressed up the ravine and turned the Usun plateau. The battalions of the 73rd and 150th now pressed forward, and the Turks, fearing for their line of retreat, were forced to retire from the plateau, which movement ended in a disorderly flight. Mukhtar Pasha now drew off his troops from the centre and left of the position; Admiradjiboff and Bronevski had to halt on account of the darkness, but Amilochvaroff, followed by the 13th Grenadiers, pressed forward along the high road, in spite of the increasing darkness, took seven guns, and advanced so quickly that when the Turkish right wing began its retreat it found the road completely barrêd, and it was only after a two days' march over the ridges of the Palandoken Mountains, during which many of his battalions disbanded themselves, that Ismail Pasha reached Erzeroum, leaving his camp, his baggage, and all his artillery in the hands of the Russians.

About 400 prisoners and 43 guns fell into the hands of the victors, whose loss was only 820 men.

The Turkish troops, especially those of the centre and left wing, were completely demoralised by their previous retreat, their evidently bad leadership, the bad example of individual officers, and their hardships and sufferings, and fought very badly.

The great demoralisation of the troops, and the reported unwillingness of the inhabitants of Erzeroum to undergo a siege, which still further discouraged the men, offered to the Russians a good opportunity for a *coup de main* against the city, on the night from the 9th to the 10th November. This failed because the columns lost their way in the darkness, and only the isolated advanced guard (three battalions of the 153rd) succeeded in surprising Fort Azizie and taking 19 officers and 540 men prisoners. An overpowering attack forced them to retire with their prisoners next morning, the three battalions having lost 632 men.

General Heimann now established at first a partial and later a complete blockade of Erzeroum, as the severity of the winter prevented further active operations, while Mukhtar Pasha withdrew to Constantinople, leaving Ismail Pasha in command. To the close of the year the positions of the opposing forces round Erzeroum remained the same.

The Blockade and Storming of Kars.

Under the supreme command of the Grand Duke Michael, after Heimann's troops had left, Lazareff began the siege of Kars, which was strictly invested. 48 siege guns having arrived on the 4th November from Alexandropol, on the 5th he began the construction of 12 batteries against the east front, about 3000 mètres distant from Forts Karadagh, Hafiz, and Khanli. A Turkish sortie to destroy these on the 5th was repulsed, and on the 11th the bombardment of the town and forts began. In spite of the heavy, uninterrupted, and most effectual fire,

the garrison and inhabitants of Kars remained unshaken; they strengthened the east front with all the means at their disposal, constructed batteries and shelter-trenches between the forts, and, being provisioned for six months, resolved to hold out. The hardships of a siege in the winter months, the extraordinarily unfavourable character of the soil for approaches, &c., and the wish to set the troops free for further operations, especially against Batoum and in the interior of the Caucasus, where the peace of the Terek and Daghestan provinces was continually being disturbed—all these causes induced the Grand Duke to order the storming of the place, which appeared to offer chances of success if the fire of the forts were first weakened, and if it could be carried out on a moonlight night when there was only sufficient light to show the columns their way and prevent disorder. The night from the 17th to the 18th November was designated for the storming, and the troops told off into columns as follows :—

Left Bank.

Lieut.-General Roop.

1st Column.	*2nd Column.*
Colonel Tscheremissinoff.	Major-General Komaroff.
2½ battalions 4th Grenadiers. 2 battalions 76th Regiment. 3 9-pr. batteries on the heights of Komkh and Djavra.	2nd Grenadiers. 3 battalions 151st Regiment. 2 batteries.
Demonstration against Muchlis and Laz Tepessi.	Demonstration against Techmas. Storming of Tschim.

Right Bank.

Lieut.-General Lazareff.

3rd Column.	Major-General Count Grabbe.	
	4th Column.	*5th Column.*
Lt.-Col. Prince Melikoff.		Colonel Bojdakim.
2 battalions 76th Regiment. 4th Rifle Battalion.	3rd Grenadiers. 1st Battalion 75th Regiment. 1st Rifle Battalion. 1 battery.	3 battalions 75th Regiment. 2 battalions 157th Regiment. 1 battery.
Storming of Suwari, and support of the 2nd Column in the attack on Tschim.	To storm Khanli.	

6th Column.	*7th Column.*	*Special Reserve.*
Major-General Alchasoff.	Major-General Schatiloff.	
2 battalions 152nd Regiment. 158th Regiment. 1 battery.	2 battalions 159th Regiment. 160th Regiment. 3 batteries.	2 battalions 152nd Regiment. 1 battery.
Storming of Hafiz.	Demonstration against Karadagh and Arab.	

General Reserve for both Banks.

Maj.-Gen. Prince Tschavtchavatze.	Major-General Dehn.
2nd Volga, 6th Orenburg Cossacks. 3rd Daghestan, Tionetian Cavalry. 14th Don Cossack Battery.	1st Grenadiers. ½ 17th Dragoons. 3 batteries.
On the Erzeroum high-road, on the Kars Tchai Bridge at Kutschukkoi, right bank.	At Komatsor, behind Tschavtchavatze's division.

Cavalry Divisions in the W. and S.W. on the Left Bank.

Major-General Scheremetieff.	Major-General Schtcherbatoff.
Caucasus Cossack Division (except Gorsko-Mozdok Regiment). 15th Dragoons, Alexandropol Cavalry.	½ 16th Dragoons, Kisliaro, Poltava, 1st Volga, 7th Orenburg, and 2nd Astrakhan Cossacks. Akhaltzikh Cavalry.
Main body in Tschachmur, to bar the Ardahan and Erzeroum roads, and connect the 1st and 7th Columns.	To bar the Erzeroum roads from Aravartan, southwards to Kars Tchai.

The night from the 17th to the 18th November was cold and clear, and there was bright moonlight. At 8.30 p.m. the columns were in readiness, and between 9 and 10 p.m. advanced simultaneously to the attack.

1st Column.—After a trifling skirmish, the village of Tschachmach was taken and the Turks forced to retire to the shelter-trenches in front of Laz Tepessi. The feeble defence made by the Turks induced the Russians to try to storm the fort, but the attempt failed; however, a fire was kept up which prevented the defenders of the fort and trenches from leaving their works.

2nd Column.—An advance upon Fort Tschim was only possible along the narrow valley between the slopes of the Techmas Hills and the left bank of the river, and by detaining the garrison of the Techmas Redoubt. Lieut.-Colonel Statevitsch therefore made a demonstration against it, while Colonel Butschkieff pressed forward towards Fort Tschim. The latter was attacked half way to the fort by the garrison of the Techmas Redoubt, but he changed front, repulsed the attack, pursued the Turks, tried to storm the redoubt, and failed. He retired with heavy loss into the valley, but was not pursued. Leaving troops to observe the redoubt, he advanced with his reserve battalions upon Tschim, captured the churchyard in front of it shortly after midnight, but in vain tried to storm the fort, being repulsed by the heavy musketry fire, and in vain tried to join hands with the *3rd Column*, which had stormed Suvari after a short struggle soon after 9 p.m., had crossed the river, and had then tried to press into Tschim between the town and the redoubt shortly after midnight. The simultaneous attack of the 2nd Column, however, absorbed so much the attention of the Turks that the 3rd Column, after an unsuccessful attack, succeeded in recrossing the river in good order.

The *4th and 5th Columns* carried both the redoubts in front of Khanli, advanced from both flanks against the main fort, and established themselves on the ramparts, while a part of the 5th Column captured a battery between Khanli and Hafiz. The columns, which had entered the main work, failed, however, to storm the defensible barrack, and being driven back by the heavy fire from it, they lined the crest of the captured parapet and thence answered the fire. The loss of the work was threatened by the arrival of strong Turkish reserves, when Tschavtchavatze's cavalry came up with two batteries, dismounted, and, in conjunction with the two columns, cleared the work of the Turks and pursued them towards the town. The brave Turkish battalion in the defensible barrack held out till 4 a.m., and then capitulated.

6th Column.—The right wing of this column under Colonel Fadeieff, of the 158th, advanced against the shelter-trenches and batteries between Hafiz and Karadagh, although taken in flank by the fire from the latter. The trenches were stormed and their garrisons pursued to Karadagh so closely that the Russians entered the fort with them, and after a short struggle made themselves masters of it, and repulsed a counter-attack from the Arab Tabia. After the batteries between Hafiz and Khanli had been taken by the right wing of the 5th Column, the left wing of the 6th succeeded in passing round to the right flank of Hafiz, and thence storming it, as the works had been battered into ruins by the siege guns. Shortly after 2 a.m., the Turkish reserves which had been posted between the forts and the town retired into the latter, and Colonel Baum took command of the 4th, 5th, and 6th Columns, and several isolated detachments which had penetrated into the town.

The *7th Column,* which had engaged the attention of the Arab Tabia till the Karadagh was taken, now advanced against the former and stormed it with little difficulty.

Towards 4 a.m. all the forts of the right bank were in the hands of the Russians, and finally the garrison of the citadel also surrendered before an attack on it was made.

On the morning of the 18th, the Turks who had crossed over to the left bank made an attempt to break through the Russian lines to the west and north-west, but were repulsed by Generals Roop, Scheremetieff, and Schtcherbatoff, while the other columns crossed to the left bank and took them in rear. The whole garrison (5 Pashas and 17,000 men, with 303 guns) was now forced to capitulate; only a few detachments of cavalry had managed to escape. The Turks had lost 2500 men, and 4500 sick and wounded were included in the 17,000 men. The Russian loss was relatively small—1 General, 17 officers, and 470 men killed; 1 General, 58 officers, and 1726 men wounded. As it was impossible to find shelter for such a large number of sick and wounded, and to prevent epidemics, the seemingly severe plan of dismissing 3500 slightly wounded Turks to their homes had to be adopted. It may easily be imagined that a large number perished miserably.

After the triumphal entry of the whole *corps d'armée* into Kars, it was broken up. Komaroff set out for Ardahan with a strong mixed brigade to protect the authorities who were organising the civil government of the district, and eventually to operate towards Batoum. His advanced guard reached Ardanutch on the 17th December, and till the end of the year he remained in the same positions. One division marched to Erzeroum to strengthen Heimann; the remainder of the corps constituted the garrison of Kars.

(*e*) The Rebellion in the Caucasus.

The insurrectional movement in the Terek and Daghestan districts gained strength steadily in September and October, and extended to Middle and Lower Daghestan, a part of Lesgia, and the Didojevza

district. The number of fighting men was stated to be 175,000, but happily they never were conscious of their full strength, nor could they ever agree upon simultaneous action. The insurrection was at its height in the end of November and the beginning of December, and completely absorbed the available troops of the 20th and 21st Divisions. By the end of the year the movement was crushed, but by no means extinguished.

At the end of the year, therefore, the Russian plan of campaign had completely succeeded, and as the military power of Turkey seemed utterly broken, it was idle to expect reinforcements for the few troops in the field before Batoum, or those shut up in Erzeroum, and the fall of those places became only a question of time.

Note I.

Reinforcements received by the Army of the Caucasus for the Second Period of Operations.

1st Grenadier Division.—Lieut.-General Roop.

1st Brigade.—Major-General Dehn. 1st (Ekaterinoslav), 2nd (Rostoff) Grenadiers.
2nd " Major-General Prince Schtcherbatoff. 3rd (Pernoff), 4th (Nesvitch) Grenadiers.
1st Grenadier Artillery Brigade.

40th Infantry Division.—Lieut.-General Schatiloff.

1st Brigade.—Major-General Gral. 157th (Imeritian), 158th (Kutais) Regiments.
2nd " Major-General Tiefenhausen. 159th (Gurian), 160th (Abchasian) Regiments.
40th Field Artillery Brigade.

2nd Astrakhan Cossacks.
6th and 7th Orenburg Cossacks.
Tiflis Irregular Cavalry.

Note II.

Composition of the Columns in the Second Period of Operations.

(*a*) Rion Column.	Battalions.	Squadrons.	Batteries.
41st Division (except 162nd Regiment)	12	0	6
2nd Caucasus Rifle Battn.	1	0	0
1st Plastuni (Kuban Rifles)	1	0	0
Gurian and Kutais Legions	0	8	0
2nd Teisk Cossacks	0	6	0
Kutais Irregular Cavalry	0	6	0
2nd Caucasus Sapper Btn.	1	0	0
Total...	15	20	6

Notes.

1. The Akhaltzikh Column (*b*) was broken up. Its troops mostly went to (*c*).
2. The Ingur Column (*e*) remained unchanged.

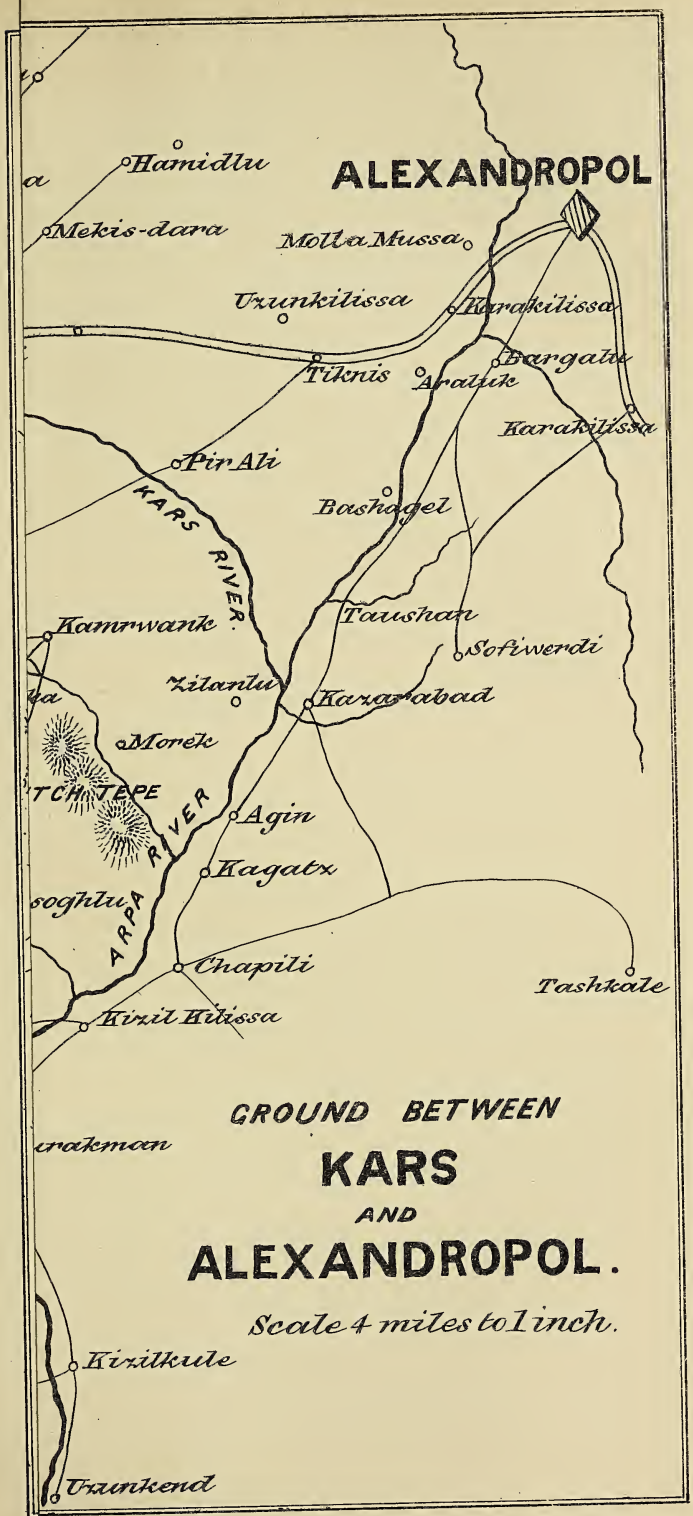
(*c*) Alexandropol Column.	Battalions.	Squadrons.	Batteries.
1st Grenadier Division	12	0	6
Caucasus Grenadier Divn.	12	0	6
40th Infantry Division	12	0	6
2nd Brigade, 38th Infantry Division	8	0	2
75th, 156th, and 2 battns. 153rd Regiments	10	0	0
1st and 4th Caucasus Rifle Battalions	2	0	0
Caucasus Dragoon Division (except 18th Regt.)	0	12	2
Combined Cossack Divn.	0	24	2
Irregular Daghestan Bde.	0	12	1
1st Urup, 1st Poltava Cossacks	0	12	0
1st and 2nd Volga, 2nd Vladikavkas Cossacks	0	12	0
2nd Astrakhan, 2nd Kisliaro Cossacks	0	10	0
6th and 7th Orenburg Cossacks	0	8	0
Irregular Cavalry, &c.	0	24	0
6/19th, 2/21st Artillery Bde.	0	0	2
3, 4, and 6/39th Artillery Brigade	0	0	3
1st and 3rd Caucasus Sapper Battalions	2	0	0
Siege Park			
Total...	62	114	30
155th Regiment, joined in October	4	0	0

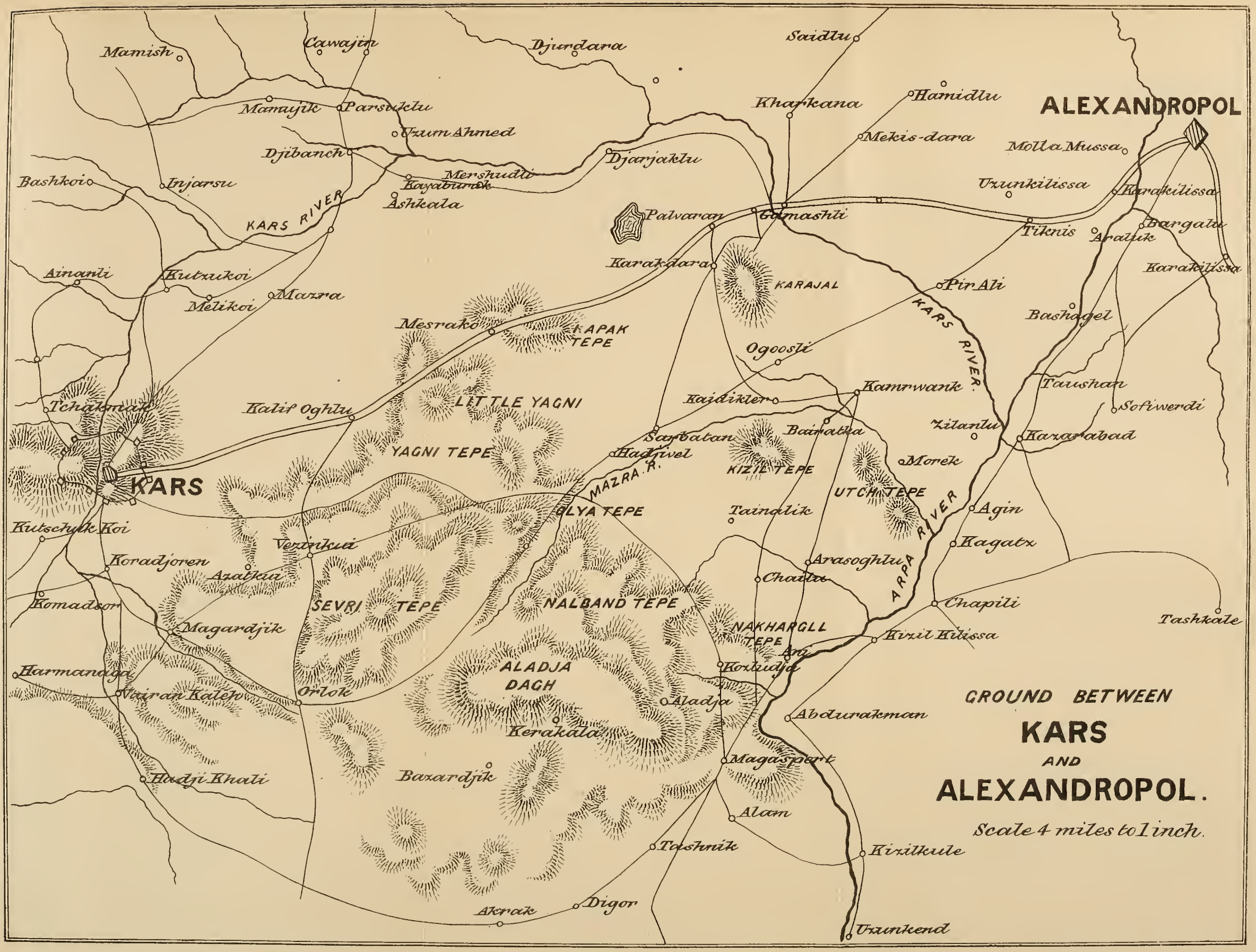
(*d*) Erivan Column.	Battalions.	Squadrons.	Batteries.
19th Division (except 75th Regt. and 6th Battery)	12	0	5
1st Brigade, 38th Division	8	0	4
1st Brigade, 39th " (except 2 battns. 153rd Regiment)	6	0	3
3rd Caucasus Rifle Battn.	1	0	0
18th Dragoons	0	4	0
1st Kuban, 2nd Choper, and Uman Cossacks	0	18	0
1st Sunian Cossacks	0	4	0
Total...	27	26	12

Note III.

The strength of the different Turkish armies varied considerably, but at the beginning of the Second Period they were believed to be composed as follows :—

Ismail Hakki Pasha.....	47	battalions,	60	troops irregular	cavalry,	7	batteries,	= 45,000	men.
Mukhtar Pasha.....	30	"	30	"	"	6	"	= 30,000	"
In Kars	13	"	—	"	"	—	"	= 10,000	"
Dervish Pasha	20	"	10	"	"	3	"	= 17,000	"
							Approximate total.....	102,000	


Hamidlu
ALEXANDROPOL
Mekis-dara
Molla Mussa
Uzunkilissa
Karakilissa
Bargatx
Tiknis
Araltik
Karakilissa
Pir Ali
KARS RIVER
Bashagel
Kamrwank
Taushan
Sofiwerdi
Zilanlu
Kazarabad
Morek
TCHITEPE
ARPA RIVER
Agin
Kagatx
Chapili
Tashkale
Kizil Kilissa
GROUND BETWEEN
KARS
AND
ALEXANDROPOL.
Scale 4 miles to 1 inch.
Kizilkule
Uzunkend


Mamish
Cawajin
Djurdara
Saidlu
Khafkana
Hamidlu
ALEXANDROPOL
Mamajik
Parsuklu
Uzum Ahmed
Djibanch
Djarjaklu
Mekis-dara
Molla Mussa
Bashkoi
Injarsu
Mershudli
Kayaburnak
Ashkala
KARS RIVER
Palvaran
Gumashli
Uzunkilissa
Karakilissa
Bargalu
Tiknis
Araljik
Karakilissa
Ainanli
Kutzukoi
Melikoi
Mazra
Karakdara
KARAJAL
Pir Ali
Mesrako
KAPAK TEPE
KARS RIVER
Bashagel
Ogooslı
Kamrwank
Taushan
Kajdikler
Sofiwerdi
Tchaldyrli
Kalif Oghlu
LITTLE YAGNI
YAGNI TEPE
Saybatan
Baiatka
Zilanlu
Kazarlabad
Hadjivel
MAZRA R.
KIZIL TEPE
Morek
KARS
OLYA TEPE
UTCH TEPE
Taindlik
ARPA RIVER
Agin
Kutschyk Koi
Verinkui
Koradjoren
Azatkui
Arasoghlu
Kagatx
Chaltu
Komadsor
SEVRI TEPE
NALBAND TEPE
Chapili
Tashkale
Magardjik
NAKHARGLL TEPE
Kizil Kilissa
Harmanaja
Aladja Dagh
Aladja
Kozludja
Vaziran Kalejo
Orlok
Abdurakman
GROUND BETWEEN
KARS
AND
ALEXANDROPOL.
Kerakala
Magasperk
Hadji Khali
Bazardjik
Alam
Toshnik
Kizilkule
Akrak
Digor
Uzunkend
Scale 4 miles to 1 inch.

EXTRACT FROM A LETTER DATED 23RD JANUARY, 1879, FROM LIEUT. F. NICOLSON, R.A., ATTACHED TO MAJOR TREMLETT'S BATTERY, WITH THE FORCE UNDER COLONEL E. WOOD, V.C., C.B., IN ZULULAND.

LAST year Lieut. Nicolson was detached with an independent command of two guns with the force under Colonel Rowlands, V.C., employed against "Secoceni," on the termination of which operations he was ordered to join Colonel Wood's column at "Utrecht," for the invasion of Zululand. In the meantime, he had arranged the equipment of his guns and packages of ammunition as hereafter described.

Country hilly but quite open, good grazing, not a tree or bush, about 33 miles from Utrecht, after crossing the Blood River. **Country.**

The transport is an enormous difficulty; 150 wagons with this column. Eight hours doing a ten mile march. No road. Every dip of ground more or less boggy. **Transport.**

Two guns, 7-prs., 200 lbs. Tandem harness. Whenever the ground admits, drawn by three mules tandem fashion; one gunner walking by the wheel mule and driving the team with long reins. No. 4 assists by leading the leading mule. **Two guns under Lt. Nicolson. Guns and draught.**

The drill invented by Lieut. Nicolson, for tandem and pack saddles. **Drill.**

Two leather boxes on each limber, ten rounds each. **Ammunition.**
Four pack mules. 80 rounds, making 60 rounds for each gun. Two other pack mules carry—on one ten double shell, on the other pioneers' tools and rocket trough. Three rockets are carried in top of each front box on limbers.
The remainder of ammunition up to 150 per gun is carried on a mule-wagon (drawn by 12 mules) driven by gunners or drivers R.A.

The tents, camp kettles, pack saddles for guns, and handy tools, &c., on same wagons. The remaining gear is carried on an ox-wagon (14 oxen), also seven days' rations for men and mules. **Camp equipage. Rations.**

Total number of mules, 26; two of which are spare. **Mules.**
Should the ground become too bad for tandem draught, the guns can be placed on mules (three to each gun), and carry 60 rounds per gun, or 40

with rocket trough and double shell, and leave one mule to draw each limber with the wagons.

Men. There are 14 men Royal Artillery, and 20 men of the 80th Foot.

The remaining four guns of Major Tremlett's battery. Two other divisions of this battery, respectively under Lieuts. Slade and Bigge, are precisely similar to each other in equipment.

Detachments. Guns, 7-prs., 200 lbs., drawn by six horses each. Detachments of five men. No. 1 mounted as usual; two on the limber; two on axletree boxes.

Ammunition. 60 rounds in the limber.
6 rounds in axletree boxes.

One Scotch cart to each division, drawn by six mules, driven by a gunner with reins and a black boy with whip, both sitting on the box; also an American wagon drawn by ten mules, driven in same manner; carry enough ammunition to make up 150 rounds per gun, with line gear, tents, one blanket per man, camp kettles, &c.

Each division has two ox-wagons in addition (14 oxen in each), to carry spare gear, kits, and seven days' rations for man and beast, and collar-makers' and wheelers' tools.

Forge. The forge is the only regimental carriage, and is drawn by eight bullocks.

NOTES

ON THE

OFFICE WORK OF A GARRISON BATTERY

OF

ROYAL ARTILLERY.

BY

MAJOR R. W. PHIPPS, R.A.

Introduction.

There is, I think, great need of a manual of battery office work that could be used by officers taking command of a battery, unaccustomed to the details of the large amount of clerical work that now falls on batteries. I have no pretensions to write such a manual, but I print these notes as a contribution towards one, placing them at the disposal of any officer who may consider them useful.

My chief aim has been to show the connection between the various books, and between the number of entries that a single casualty may render necessary. There is nothing new, original, or untried in these notes. The system of accounts is that enforced in India, while the instructions designed to keep up the connection between past and present entries, accounts, and letters, and to facilitate reference, are taken, often literally, and always in spirit, from the orders of the old 10th Brigade when under the command of Colonel (now Major-General) H. P. Goodenough.

One omission may be explained. Many officers are intent on having a system of cross-totalled accounts, by means of which they believe they can obtain perfect security against loss. No possible form of accounts prevents fraud; and as for errors, a clerk that cannot keep a simple system correctly will break down any complicated plan, and will, by erasures and corrections, reduce the cross-totalled sheet to a state of chaos. Whenever I have been able to watch the progress of one of these complicated systems, sooner or later a breakdown has occurred, the explanation being "It worked beautifully, but my Pay Clerk is ill in hospital, his assistant is in the guard-room, and I have been too busy to attend to it." It does not do to rely on a system that fails the moment any pressure comes on the battery, and that requires trained clerks to work it. If a battery has time to cross-check all its accounts, by all means let it be done; but the permanent system must be the very simplest possible. At present it is a mere chance whether a garrison battery has a Pay Clerk at all; and as far as my experience goes, I think it best to try to avoid any calculations or clerical work that can be spared.

I should be glad to receive any suggestions from officers who may take an interest in these matters of ordinary routine.

Battery Books.

The chief books that a battery has to keep are as follows :—

A Rough Scribbling Diary for the Year.

1. This always remains on the office table, and is useful for noting in advance the dates on which any special returns, &c., are due. Thus, on 1st January, Gunner Robinson applies for his discharge; an entry is at once made in the diary, under date 31st January, "Send in application for discharge, No. 41, Gunner James Robinson."

The Battery Cash and Balance Book.

2. A form for this book is given in App. A. The form for the monthly balance sheet is given in App. B. The cash book is a record of all cash transactions of the battery, recorded at the time of the payment, or of the receipt, and always bearing the real date of the transaction. Thus, in the form given, the first instalment of the sum due from the Paymaster-General for the month of February reached the Major on 29th January, and is therefore included in the January cash account. So, also, it will be seen that a good many of the bills due for December were not paid till January. Thus, the canteen bills for the last week in December only reached the Major on 1st January; they were paid on 2nd January, and therefore came into that month's transactions. In other words, the cash book is so kept that, if balanced at any moment, it shows the exact state of the cash in hand at that moment, without any reference to what month the items refer to.

3. I find it objected to this sytem that it is only good for trained accountants; and that it is simpler to keep the cash accounts for each month separate, so that a debt due in December, but not paid till April, would still appear in December's cash account. I think this objection is obviously wrong; it entails keeping the cash accounts of one month open till long after the succeeding month's account is begun, and it makes it difficult to tell at any moment what cash is in hand. The system I advocate has the great advantage of being in exact accordance with the facts. The most inexperienced man can be expected to put his actual transactions down in regular order. He has only to say to himself, "I got £170 on 29th January; down it goes on that date." Surely this is simpler than to say "I got £170 on 29th January, but I must not put it down then, I must keep it till the February cash account is open." Under which system is an inexperienced *locum tenens* most likely to go wrong?

4. Each entry should be complete in itself, as far as possible, so that it may be understood if referred to years afterwards. Thus, a payment entry :—"Gunner Smith, cash £2 10 0" is a bad entry. "No. 1472, Gunner James Smith, cash balance of December 1878 account £2 10 0," is a good entry. The payment in App. A., to Officer Comdg. 6/22 R.A., dated 8th January, is obviously better for reference than if it had been put thus :—"Officer Comdg. 6 Battery, 22nd Brigade. Balance of debts and credits of

transfers £1 3 8." All entries should be verified whenever possible by the signature of the recipient; this rule holding good for entries on the receipt side as on that for payments. There ought to be no question as to what officer received any money.

5. Each item should be, as far as possible, kept separate, so as to make checking easier. This rule may appear broken in the entry of payment on 8th January, and it would have been better if the receipt of Gunner Maher's debt could have appeared on the receipt side; but if that had been done, the payment to the 22nd Brigade would have appeared as £1 9 0, whereas the cheque sent was only £1 3 8, and this might have caused confusion if the item had been referred to. As it now stands, the amount paid by the cash book and by the cheque book agree. Nothing can be better than to keep always in your mind "How would this look to an utter stranger investigating the accounts three years hence?"

6. It ought not to be necessary, but I fear it is, to say that no cash account can be shown as in debt. As it represents all the sums paid and received, the Major cannot have paid more than he got. If any advance has had to be made by the Major, or by any fund, to keep the battery going, it must appear as a receipt.

7. The weekly pay is managed as follows:—The Nos. 1 having prepared their pay books, and entered in the pay sheet for the week the name of every man of their subdivisions, the Pay-Serjeant takes the battery ledger, his assistant the pay books, one by one. The assistant reads out the men's names, the Pay-Serjeant judges quickly from the state of the man's sheet how much pay ought to go to him that pay day—say, for example, five shillings; the assistant enters that sum in the pay book, the Pay-Serjeant in the ledger, in the columns at the left hand upper side for cash payments; and so on. Of course at the end of the month the amounts have to be more carefully taken from the ledger, so as to make the accounts balance. The totals of the pay books and the washing bills give the amount required for the whole battery; this is brought from the bank by an officer, and the proper sum placed on each pay book. The Nos. 1 are now called in, each counts his cash, and, if it be correct, goes up to the Major, signs the cash book (see entry for 7th January), and then proceeds to pay his men, in the presence of an officer, one room being used for that purpose. Thus in half-an-hour a large amount will have been paid, and its payment verified by the signature of the men in the pay books. A small percentage of the men may not have been paid, but very little money will be left in the hands of the N.C. officer. Sometimes, to avoid corrections or returns of pay issued for men gone sick, &c., it may save trouble to not let the Nos. 1 sign till the pay is altogether, or nearly altogether, issued; but the principle remains the same. A N.C. officer has no means of keeping any money in security in barracks. By this system he, at the utmost, can only have about two men's pay to keep for an hour or two after leaving the pay-room. The officer superintending the actual payment does not allow any N.C. officer to leave with a large amount of cash. It has to be returned; and an example of this return of pay issued, and of its subsequent re-issue, will be found in App. A., under dates of 7th and

8th January. The extra clerical work this may entail in a year will not be so great as what would follow a disappearance of any cash.

8. By the entries on the form given it will be seen that at the end of the month the sums due to the tailor, shoemaker, &c., are carried to the credit of the funds of these several designations. This saves trouble, as it clears the balance sheet. For example, the boot bill may amount to £7 16 11, and of this only £2 5 4 may be due to the shoemaker, the rest to the tradesman that supplied leather, &c.—arrangements that had better be kept separate from the battery cash. A description of a book for containing the accounts of such funds will be found in par. 21.

9. One important point has to be settled. Who is to keep the cash? Pay-Serjeants have no means of keeping money in security; they are liable to be robbed at any moment; and, except they are experienced men, they are very likely to get confused in their accounts, when the sudden discovery of an actual or apparent loss upsets them. I believe the real history of many a fraud on a battery's cash has been that the Pay-Serjeant has found himself to be apparently deficient of money, has been afraid to own it, has been sure it will come right, has done anything to hide the state of affairs for the moment, till he has got himself involved in a regular net of fraudulent transactions.

10. What trouble is it to the Major to keep the cash? The weekly pay is easily managed. (See par. 7). All large bills are settled by cheques; and with an ordinary battery there are very few other cash transactions.

11. The Major, therefore, keeps all the cash, except a small amount—say two pounds or so—left in the hands of the Pay-Serjeant to meet any sudden emergency. This does not involve two cash books, as each time such a payment is made by the Pay-Serjeant, he reports at the next office hour to the Major, and recovers the amount; his cash always remaining a fixed quantity.

12. There is really very little trouble about this system, and it has the great advantage of giving a character of openness to the accounts. No accidental or intentional alteration of figures, or inaccuracy in amounts, changes the position of the Pay-Serjeant. For example of the other plan: in one battery a Pay-Serjeant contrived to get about £300, by altering, from time to time, the figures of the savings bank accounts. By the system given here, all such alterations would have only had the effect of giving the Major more cash in hand than he could properly account for.

13. There is probably no more honest or hardworking class than Pay-Serjeants; but the constant interruptions to which they are liable in their work make it necessary to relieve them from all fear of the cash not being right.

Balance Sheet.

14. The cash account is not complete security without a monthly balance sheet, a form for which is given in App. B., so framed as to permit its being made out on the pages ruled ready for the cash account. Thus, when the

cash account for January is closed, the next two pages are left blank for the balance sheet, and the cash account for February is begun on the 3rd page.

15. The balance sheet is the final test of the state of the accounts. It is not easy to make out fraudulent balance sheets that will escape detection month after month, if the Major keeps the cash; while, if honestly and continuously made out, any errors in the accounts are sure to come to light. It must contain a statement of every debt due from the battery, no matter to whom; and of all cash or claims that can be treated as assets. Thus, a man's debt in the ledger is obviously a credit of the battery, while the credits due to the men are clearly debts due from the battery. So also with the debts and credits in the mess books. The full amount of each item must be set down, not the balance only that may result from a counter-claim. For example: if the debts in the ledger are £10 and the credits £6, it would not be right to put down on the credit side a balance of £4, as you must pay all the credits and may not get all the debts. In the Appendix the balance sheet is made out for December, 1878, the month previous to that of the specimen cash account, to show how the items are worked off.

16. The form given is very simple, the items on each side being grouped under four divisions:—1st, the amounts due to or from the Major; 2nd, those concerning the men; 3rd, those concerning the Paymaster and Government Departments; 4th, those relating to other batteries, and other miscellaneous entries. Each item should be kept separate, and if disposed of, should have the date of the sum being paid or received put against it, so as to show that it is not to be carried on to the next balance sheet. Thus, the debt due to Officer Comdg. 6/22 on 31st December, 1878, was paid on 8th January, 1879, and is marked off. It will not re-appear in the balance sheet for January; but the debt to Mrs. Allan has remained unpaid, and will therefore be entered in the balance sheet for January, at the head of the miscellaneous items, where it will re-appear, month after month, till paid off. Never allow this sheet to be fictitious in any manner. I mean that every item that belongs to December, not really paid or received before the 1st January, must appear in the December balance; and the sheet must be in exact agreement with the cash account. Thus, the first instalment, £170, for January, was not due till that month, but as it actually was received on 29th December, it appears in the December balance sheet as a debt, thus neutralising the apparent excess of cash in which it is of course included. The canteen bills for the last week in December were due on the 31st of that month, but were not received or paid then; they thus figure as a debt.

17. In preparing your balance sheet, first insert all the old items remaining unpaid or unreceived in the same order as for the previous month, going carefully over your December cash account to see that none of them have been wiped out. Payments or receipts made in December for past months —November, for example—will not appear in the balance sheet; those for future months, of course, must. Then, as the sheet will not be closed till some time after the January cash account is open, go carefully over that account to see what payments have been made in that month for sums due in December. The balance sheet should be all ready, so that the moment

the balance is struck in the pay list in pencil it may at once be transferred to the balance sheet, and the final balance then struck, at first, in pencil. The nearer the resulting balance is to that of the previous month, the more probability of its being right. Often a startling discrepancy will occur, and a beginner had better then compare the two balance sheets (November and December in this case), and see if any items similar in character—credits in ledger, for example—differ very much in amount without a ready explanation. It is well to remember that a mistake of £10 is as likely to be made as one of a penny—the mere amount is nothing; in fact, very often a large amount is omitted from it not being entered at once, its amount making one feel sure one will remember it. Remember also that an error of a sovereign in the balance sheet may mean something much larger; it may only be the balance resulting from two different errors.

18. A battery that keeps up a balance sheet from month to month, or more properly strikes its monthly balance sheet regularly, can hardly go very far wrong; but it is of little use to only prepare a balance sheet occasionally.

19. Here it is unfortunately necessary to remark that the balance thus struck is never carried on to another month; the whole sheet starts fresh each month, only retaining any items that may still remain unsettled.

20. The rule given as to items in the cash book containing a complete history of themselves applies with greater force to those of the balance sheet. If the detail of any item is very long, and the item not soon wiped out, give the detail in full once, and then afterwards refer to that month thus:—"For detail, see August 1876."

Fund Book.

21. There are other cash transactions—those with the various funds, canteen, refuse, cricket, recreation, shoemakers' and tailors' shops, and the necessaries funds. The stoppages for these having been charged against the men, and so collected by the battery, are entered in the cash book on the last day in the month as transferred to the various funds. Some of these funds may have their separate account books kept by their own treasurers, but the Major should always have this duplicate account, in case of the loss of the separate one. It is a good plan to use for this purpose one large book to hold the accounts of all the funds, the top being cut for a list of the funds, as is done for an alphabetical index. With some of these funds it may be necessary to strike a monthly balance, in the same way as is done with the battery, the cash in hand and the stock in hand being usually the only assets, and any bills due the debits. The filed receipts should be in the Major's possession.

Battery Ledger.

22. The ledger needs little explanation. At the top of each man's sheet should be entered a brief note to show wherefrom the account is brought;

thus :—"From p. 142," or "From p. 281, old ledger," or "Transferred from 9 Battery, 22nd Brigade, R.A., 1st January, 1879." At the foot of each page on which an account is so far ended, should be a similar note to show whereto the account is carried, or why it is closed; thus :—"To p. 50, new ledger." "Transferred to 9 Battery, 22nd Brigade, R.A." "Discharged at Woolwich, 16th January, 1879." "Deserted, 29th January, 1879, balance credited in February, 1879, pay list." Each entry of a charge should be as complete in itself as possible; thus :—"Overcharged, December 1878, 7d.," is a bad entry; while "Overcharged, December 1878, 1 hospital stoppage (31st) 7d." is a good one. When men are transferred to the battery, copy, if there is room, the ledger sheet they bring with them into your ledger, to commence their account; it is often useful as a record. No erasures should be allowed in this or any cash account, or, indeed, in any document of the slightest importance. The detail for checking the ledger will be found in pars. 66–7.

Savings Bank Ledger.

23. The same remarks, showing wherefrom and whereto an account is carried, should be entered here. At the beginning of the ledger should be pasted one of the printed forms giving the various amounts of interest. In the ledger itself should always be kept, fastened by clips, all the transfer forms received during the current year. There also should be kept, pinned to the ledger, Savings' Bank Voucher No. 2, for deposits and withdrawals for the current month, in duplicate. Take care to distinguish gratuities from ordinary accounts, in the ledger, and in all transactions.

Necessaries Ledger.

24. This is a store account of all necessaries, on the same principle as a wine-cellar book, giving first the number of articles in store on the first of the month, those received during the month, the total of these, then, below, the number sold, then the difference, which should be the number in store at the end of the month. Below all this comes the detail of the articles issued and of the men who received them. It is difficult to get this book kept up, and really used for the actual issues; clerks being fond of substituting pieces of paper to hold rough lists, to be afterwards entered, if remembered, in the ledger. Some batteries make the man sign for the issue.

Clothing Ledger and Equipment Ledger.

25. I do not propose going into detail on these ledgers, for several reasons. The clothing regulations are at present not quite certain; at least, the decisions given to different batteries do not always agree. Certain rules, however, apply to both ledgers. Enter every receipt and issue at once. Fasten firmly, by clips, at one end of the ledger, all delivery vouchers and "transfer clothing returns received;" at the other end, all receipt vouchers and "transfer clothing returns sent." Whenever any article is lost or made away with, enter a note so that any stranger can long afterwards ascertain all that has been done; thus :—"1 waist belt, lost 13th June, 1876, by No. 46, Gunner D. Keating; amount, 2s. 9d., recovered from him July 1876; credited in pay list, July 1876, item 26;" or "Taken away on desertion,

26th June, 1876, by No. 94, Gunner J. Elton. (See Court of Inquiry, dated 17th July, 1876, Woolwich, attached.)" If this be not done, it is very difficult to answer references that are often made years afterwards.

Size Roll.

26. The regulations lay down that a man's height, chest measurement, &c., are to be yearly entered in his pocket ledger, which is practically useless, as the ledger is always with the man; and, having the man, one has the information. What is really useful is a book giving every man's measurements, and the actual sized tunic, patrol jacket, trousers, Wellington and ankle boots, that fit him; so that when the man happens to be away, you have the information that enables you to demand, or send, the exact sizes required. This book should be checked about 30th April each year, after the issue of the clothing, and is used for compiling the requisition for the annual clothing.

Transfer Clothing Return Book.

27. All clothing transfer returns, received or sent, should be copied into a book, printed for the purpose, with the same heading as the return, but lengthened vertically to include many names on one page, and omitting all the notes at the bottom of the return. The returns "received" are copied into the beginning of the book, those "sent" into the end, working backwards, so that the two sets eventually meet in the middle of the book, when it is full. This book is necessary, because the duplicate you keep of the returns sent with transfers from you, as well as the originals you receive with transfers to you, have to go with your clothing ledger to Pimlico for audit at the end of the year, so that you then have nothing to refer to. The entry in your ledger of clothing sent or received does not hold good against another battery, in case of any dispute arising; you require the statement received or sent. These transfer returns are very liable to be lost, and in the case of transfers from or to batteries abroad, may take long to replace. This book, therefore, will be very useful.

Register of Great Coats and Capes.

28. Gives a list in detail of each great coat and cape ever in possession of the battery, with columns for the dates of issue and of re-issue, the names of the men that have worn it, and the dates on which these men have received or given it up. It must be remembered that the history of the coat is the first object in this book; it is not a mere list of men, with the coats worn by them. Ample space should be given to each coat to contain all remarks, especially notes as to its final disposal:—"Brought from 4/21 by No. 47, Gunner James Colville, on transfer, 10th August, 1878." "Condemned by Board of Survey at Woolwich, 12th August, 1878; returned into store, Arsenal, Woolwich, one of 18, under authority ....."

Ration Book.

29. Large sums may be lost by carelessly overdrawing rations. Attention to keeping up Form 102 for attached men, as suggested in pars. 46, 61, and

62, will prevent some losses. To stop the battery overdrawing, a book can be prepared giving the number of men in each mess at the beginning of the month, the number of rations drawn by each mess daily, and all casualties in each mess. Remember that when a man is deprived pay for being absent without leave more than two days, the mess is very apt to draw a ration or rations that they are not entitled to. Thus, if a man is absent from 11 p.m. 1st June to 1 a.m. 3rd June, the mess will, if not watched, draw 30 rations that month for the man instead of 29; so that the return of men mulcted pay must be used to check the book. Also, before drawing ration-money for any man on pass or furlough, refer to this book to see if the mess have allowed for the casualty, and for the consequent diminution of the number of rations.

Letter Book.

30. It depends on how this book is kept, whether it is of real use or not. You have to remember that in working a battery you are running a machine that ought to be in such state that the officer who may at any moment receive it over from you shall find full details of all past transactions ready to his hand. Thus a letter, "In reply to your letter, I have the honour to inform you that the articles were received from the man and disposed of as you requested," may be quite intelligible at the time; but if Major and Pay-Serjeant change, and a year afterwards reference be made as to what has become of, say a belt belonging to another battery, such a form gives no help. Again, a letter intelligible to you may not be so to the receiver. "Please state where Gunner Brown is," for example, was answered, "Which Brown—I have had ten from your brigade?" In each case it would have been a little longer, but much clearer, to have written "In reply to your letter, No. 115, of 4th May, 1889, requesting me to take a waist-belt and frog of your battery from No. 120 Gunner James Cullen, recently transferred to me, and to give them to No. 140, Corporal George Smith, of your battery, attached to mine, I have the honour to state that this has been done. Corporal Smith's receipt is attached." Or, "Please state where No. 4126, Gunner George Brown, No. 5 Battery, 29th Bde. R.A., now is. When last heard of (in June 1878) he was attached to your battery."

31. Keep your letter book with the inner half-margin always blank at first starting. When a letter refers to another one written by you before on the same subject, turn back to the previous one, and enter in red ink on the margin, "See also No. 112, of 4th May, 1899;" so that in the case of any long correspondence, coming across any letter, you can trace the whole series. Answers to your letters received, if short, can be copied into the margin in red ink. If they must be separate, put them into the guard book for "Letters Received," inserting in the margin of your letter, "See p. 96, Letters Received. Officer Comdg. 5/25, of 24th July, 1899, claim paid," or some similar remark. Go over your letter book occasionally, to see that this has been done, and that no subject has dropped in error, at the same time inserting similar remarks when necessary. "Received." "Settled." "Application sanctioned; man discharged, 4th September, 1899."

32. The "Letters Received" should be gone through in the same manner, with similar remarks. "Sent." "Answered by 115, of 2nd July,

1899, No." "Paid on 5th August, 1899, by cheque." "Paid on 7th August, 1899, by P.O. order to A. Davis from J. Clarke."

33. Here we part for a time with the Pay-Serjeant's department. He takes all finance, stores, clothing, necessaries, and barrack affairs. The Serjt.-Major takes all numerical and nominal returns not required for pay purposes, punishment and promotion returns, attestations, casualty returns, and defaulter books, and everything connected with arms and accoutrements; he therefore keeps the equipment ledger, mentioned for brevity's sake in par. 25.

Attestations and Register Sheets.

34. These are very important documents. They contain the whole history of a man's service; and if the Regulations ordered all the certificates and qualifications the men possess to be entered on these sheets, they would give a complete description of the men. It is also a pity that trades are not altered more. A man enters the service describing himself as a "labourer;" twenty-one years afterwards he is discharged a trained servant, groom, or mechanic: he still figures as a "labourer." The manner in which entries are made will be described in par. 68. Every man is identified by his number, Christian name, surname, age at attestation, and date of attestation; so that frequent references to the attestations are necessary.

Casualty Book.

35. The most important book in the battery, but not required to be kept by any regulation. As the original attestations, of which the battery has only copies, are kept at the Record Office, Woolwich, every transaction that necessitates an alteration or an entry in the attestation has to be reported as a "casualty." Joining a fresh brigade, losing or getting a good-conduct badge, forfeiting or recovering service, being wounded or getting a medal, being promoted or reduced, being imprisoned or tried, changing religion, altering the address of the next of kin, marrying, being put on or removed from the married roll, having or losing children, or baptising them, being discharged or dying, are all casualties. A return of all these casualties goes in, in duplicate, every month, and a copy should be carefully kept in a large book; and as every one sooner or later is mentioned in it, this book gradually contains a history of every man, woman, and child while with the battery, and is very useful. If it is treated as a common return, and filed in a guard book, it loses most of its practical value, getting confused with other returns, and is probably burnt after a few years, as the books get too full. The only addition to the regulations to be noted here is, that it is convenient when a man is discharged to enter in this book his address in the column of remarks.

Rough Casualty Book.

36. A book in which all casualties are entered as they occur, in any order. For example: a man is posted; his name is probably spelt wrongly in the orders, but it goes down at once, to be corrected on arrival of his papers. Another man's attestation is called for, preparatory to discharge;

it may never be returned, so down at once goes the man's exact name, age, and date of attestation, with the note "for discharge." Thus, at the end of the month, all the materials for the casualty return are ready, and you are not dependent on the memory of a clerk. It must be clearly understood that this is to be a "rough" book; no piece of loose paper is to contain the first entry. Let the book be dirty or dog-eared; that is only a proof it is really used for its purpose. All that is important is that it should be made up to date.

Battery Defaulter Book.

37. Contains a sheet for every man, with an entry of every crime, too often written on the worst possible paper, whereas a tough untearable material ought to be used. At the top, for the present heading, substitute after the man's name his date of attestation and his age at that date. It is well to, at least once, go carefully over all these sheets, to see that the men's real numbers and names are entered thereon in agreement with the attestations. Often the change of a man's name is not carried out. The dates of imprisonment and of forfeiture of badges should also agree with the attestations. At the top of each sheet, write "1st Sheet"; at the foot, when a new sheet is opened, write "Continued;" on the next sheet, "2nd Sheet;" and so on. For want of these precautions many a sheet is lost, with the following effect:—Suppose a man's first sheet with his serious crimes disappear. They remain in the regimental sheet in the Adjutant's office, but in the meantime the man may for years be treated as if he had no entries except on his remaining sheet. The regimental sheets, containing only the more serious punishments, are kept by the Adjutant, and the two sets of sheets should occasionally be compared. Great differences will often be found.

Monthly Punishment Return.

38. Is the means by which the regimental defaulter sheets are kept in agreement with the battery sheets. In form it should be exactly the same as a defaulter sheet, except that it ought to contain a column for date of the last previous regimental entry, to prevent any one dropping out; and all regimental entries should be copied into it by the battery, word for word; and from it, in the same manner, in the brigade office, into the regimental sheet; so that the two entries may be identical. The importance of this is often overlooked in both offices. This return is one of those that should be opened early in the month, and checked weekly; not left to the end. It is a good plan, whenever a man arrives from a voyage, or from a battery that has been moving, or from detachment, to report all his last regimental entries, in case of accidents. The Major himself should check this return carefully with the defaulter sheet, the casualty book, and the court-martial return.

Court-Martial Return.

39. This return should also be opened at the beginning of the month, and each trial entered as soon as the proceedings come in. This return checks with the casualty return and the punishment return; the bottom lines are checked by the return of fines and of men deprived pay. (See par. 48.)

Brigade and District Monthly Returns, and Weekly Increase and Decrease.

40. One set of remarks will do for these and all similar returns. Nominally due on one day, they are often called for several days in advance, and thus a casualty affecting them gets overlooked. For example: the brigade return may have to go in on the 28th of the month; a man is discharged on the 29th, and in making up the next return, that nominally commences on the first of the next month, this discharge is likely to be left out if there is any change of clerks. All such returns should therefore have the columns giving the names of men "joined" or "gone" kept up from day to day, each casualty going in as it occurs. For this purpose the battery copies of these returns, and especially that of the brigade returns, should be kept in a printed book, that OUGHT to be supplied by Government.

Register of Arms and Accoutrements.

41. Gives a list in detail of every article forming each set of arms and accoutrements, and the date of issue of each article. A side column gives the name of each man that has held the set, with the dates of issue to him and of his giving them up. Any loss or replacement of any article should be carefully noted as in the equipment ledger (see par. 25); the date of issue of the lost or returned article being struck out, and that of the one replacing it inserted. This register must be treated as an account and history of the arms, not merely as a list of the men that have carried them.

Certificate Book.

42. Have a book, cut like an alphabetical index, to contain spaces for lists of certificates of education, long and short courses, Gymnasia, Laboratory course, wheelers', smiths', and other courses, and any really ascertained trades. Any useful qualifications might also appear as headings—"Skilled Swimmers," "Rowers," "Climbers," &c.

Married Roll.

43. Should contain, first, the names of all men married and on the establishment, and their families, giving date of first being brought on the establishment, and of what battery, also date of being brought on establishment of the present battery; secondly, at considerable interval, or at the other end of the book, the names of all men married with leave waiting to come on establishment, giving dates of marriage and the name of the officer granting leave; thirdly, the names of all men married without leave. In all cases, the date of marriage and the names of the wives and children, as well as dates of birth of the children, should be given.

Register of Marriages and Baptisms.

44. Requires no explanation. On the transfer of a married man, his marriage and the baptisms of his children are entered here, as well as fresh occurrences.

General Orders, Army Circulars, General Regimental Orders.

45. All these printed orders should always be kept in spring clip cases till the end of the year, then removed and bound. These cases for holding them are very useful. (See also par. 73.)

Daily Work.

46. Let us suppose that, as a beginner, you mean to go fully into each part of the daily work, to see how the different entries fit into one another. You have on your table the rough diary described in par. 1, and a wooden tray, foolscap size, holding all documents put aside for consideration. W.O. forms 312, men deprived pay for absence, 55 for fines, and 102 for rations attached men not on pay, are also on your table; while the Pay-Serjeant gives you another tray, with all fresh letters, and such of his work that may be ready for you.

47. The last night's orders direct that an escort is to start in two day's time; this goes down in the diary against the date named. You open the letters; some can be answered at once, or merely require passing, in which the date should always be used; others go into the tray for reference. Next come the prisoners.

48. Gunner Elton has been deprived two days' pay, and thereby has lost a badge. The crime is entered by you in the defaulter sheet, and initialled by you, and the two days' pay lost entered in the W.O. Form 312 at once. The Pay-Serjeant enters the loss of the pay and then of the badge in the man's ledger sheet. The Serjeant-Major enters the loss of the badge in the rough casualty book; then he, later, copies the whole entry into the punishment return. You, later, enter the loss of the badge on the man's attestation. Gunner Winton has got seven days' cells. The Colonel has written his sentence on the original crime; the Adjutant ought to give you a certified copy of this on the duplicate. A commitment to the cells is filled up in the Colonel's office, signed by him. The prisoner is sent again to the hospital, to be medically examined a second time. The crime is recorded in the defaulter sheet and punishment return, and the loss of pay consequent thereon noted in the ledger sheet. Gunner Dennis has been fined for drunkenness. The fine is recorded in the defaulter sheet, ledger sheet, the special list at the end of the ledger, and in the return of fines on your desk.

49. The proceedings of a court-martial lately held on Gunner Powel have just reached you. The crime, an abstract of the charge, is entered in the defaulter sheet and punishment return, and the loss of pay recorded in the ledger, from date of awaiting trial to end of sentence. The casualty then goes into the rough casualty book exactly as it ought to stand in the fair return, and the proceedings are copied into the court-martial return. You check and initial the return, and send off the proceedings to the Adjutant. If there is a reduction of rank, enter it in the man's pocket ledger. Enter in your rough diary the date of the man's release. Later, enter the casualty in the attestation. Any imprisonment has to be entered in the medical history sheet.

50. Gunner Ryan, who belongs to your battery, but has been away on

detachment out of the district, rejoins. An entry is at once made in the monthly district return, under the head "joined." The brigade and weekly increase returns are not affected in totals, but only in the distribution. His kit, arms, accoutrements, and clothing, are carefully examined. Any regimental entries incurred since he left you had better go in the punishment return.

51. Serjeant Alton, who is out of the district, is posted to your battery. The entry goes into the rough casualty book, to be corrected if necessary when his documents arrive, and an entry under "joined" is made in the brigade and weekly increase return. The district return remains unaffected in any way till he actually comes into the district.

52. Corporal Hilton, who has been transferred (say, for some special reason) as Serjeant out of your battery and district, comes in to be settled with before leaving. He has already given up to the Serjeant-Major his arms, accoutrements, and gaiters; these, especially the waistbelt and carbine, have been carefully examined, and any damage charged for. His kitt has been examined by the subaltern, when the Pay-Serjeant, if practicable, was present, and saw that he really had the articles of clothing shown in his transfer clothing return. He first goes to the Pay-Serjeant, to whom he gives the numerals off his tunic, jacket, and great coat; his transfer clothing return is read and explained to him, and he signs that and the duplicate. His pocket ledger is examined to see if his clothing and savings bank accounts and his deferred pay are correctly entered. He then reads and signs his ledger account, receives from you his cash balance, and signs for it in your cash book; you sign his pocket ledger. This is the time to get from him any special receipts you may require. He then goes to the Serjeant-Major, who strikes a line through his name wherever it occurs in the certificate book (par. 42), and marks him as "gone" in the register of arms (par. 41), and in the married roll (par. 43), date and full particulars being given. If he is on the married establishment, you cannot fill his vacancy till he is absorbed in that of his new battery. The Serjeant-Major then ascertains that his promotions and certificates, and the entry of his being on the married establishment, are all properly entered in his pocket ledger; and, if all is right, he gives the Corporal his route and warrants, having first entered the number and date of the route in the diary. The Corporal now can go.

53. The Serjeant-Major then sees that the casualty is properly entered in the rough casualty book (par. 36), and brings you the attestation and defaulter sheet to sign. He sees that the departure is entered in the weekly return of increase and decrease, in the district return, and in the monthly brigade return, and strikes the name off his duty roster. The next day's morning state is affected by this casualty, as is the weekly duty state.

54. The Pay-Serjeant makes the proper entry in the register of great coats (par. 28), and in the savings bank ledger, to show that the man is gone; strikes off his clothing in the clothing ledger, has the transfer clothing return copied into the book (par. 27) for that purpose, and clips the duplicate return into the clothing ledger. He then copies the man's ledger sheet, getting you to sign the copy, and putting at the bottom of original and of copy "Rationed up to and for 6th January, 1879; no savings bank

deposit," or "has a savings bank deposit," as the case may be. Any stoppages that the man is under, unrecovered fines, &c., should be noted at the foot of the ledger sheet, as well as on the No. 1 Report, which is now prepared. The transfer savings bank form is made out, care being taken to distinguish between the form for deposits and that for gratuities, and it is signed by you. The Pay-Serjeant now collects the man's documents. It is strange how many mistakes are made as to what these documents are. Wherever a man goes for duty, there his battery defaulter sheet, his ledger sheet, and medical history sheet must be sent, as well as the No. 1 Report. If he is transferred, then his attestation, extract of marriage and baptisms register, certificate that he is on the married establishment and that his place will not be filled up till he is absorbed, transfer clothing return, transfer savings bank, all go too. The fact of his being on the married establishment must be entered on the No. 1 Report. His name is struck out of his subdivision pay book, and out of the ration book.

55. Gunner Allen has joined some days before on transfer; his documents have now arrived. His pocket ledger, defaulter sheet, medical history sheet, and the entry in the rough casualty book are compared with his attestation. Any regimental entry that has occurred just before his joining had better go into the current punishment return. All his certificates and qualifications are entered in the book for that purpose (par. 42). His name is entered in the register of arms against the particular stand delivered to him, any damage to which is noted at the time. His name is entered, if entitled, on the married roll; and the certificates of his marriage and of his children's baptisms are entered in the register. His medical history sheet is sent to hospital, and his address is noted. The certificate received from his former battery that he is on the married establishment, and that his place will not be filled up till he is absorbed by you, is carefully filed. His bed ticket is made out and given to him. The entries of his marriage, &c., in his pocket ledger are compared with W.O. Form 771 sent with him. The entry of his deferred pay in his pocket ledger is compared with his attestation. He is now handed over to the Pay-Serjeant, who ascertains that his pocket ledger is signed, and agrees with his ledger sheet, and that the entries of his clothing in the pocket ledger agree with his transfer clothing return, and that he really has that clothing, properly marked. This clothing is at once entered in the clothing ledger, and the transfer return clipped to the clothing ledger, after being copied into the book for that purpose (par. 27). His savings bank transfer is compared with his pocket ledger, and then is clipped to the savings bank ledger, in which a fresh page is opened for him, showing date of transfer and where from. If he is not shown as having a deposit, see that none is shown in his pocket ledger. Take care no mistake is made between a gratuity and a deposit. His name is put in the index of the savings bank ledger. His great coat and cape are inspected and entered in the register (par. 28). His ledger sheet is compared with the No. 1 Report, or Form 97, sent from the Paymaster, and if practicable copied into the ledger, with remarks to show wherefrom he is transferred, and his name is put in the index. The ration book (par. 29) is checked by the No. 1 Report. His numerals are given him; for tunic, jacket, and great coat.

56. Gunner Dalton's papers are called for by the Adjutant, as he has

applied to be discharged. Before sending them, you enter in your rough casualty book the man's name, date of and age at attestation, and have the voucher for deferred pay (W.O. Form 361) made out, unfinished. This is a good time to go over the man's accounts with him, and see if he has any grievances. A gunner seldom voluntarily makes a claim till the last possible or impossible moment. If left to himself, he will, when leaving the office after discharge, suddenly claim a day's working pay, due about a year back, on a date that he does not remember; he forgot to claim it at the time; he does not know who was in charge of the party—rather thinks it was Serjeant Smith, who went to India nine months ago. When the Board sits, you attend, see that the man has his pocket ledger ready, signed up to that day by you; and you sign the Board, as witness to his signature. Take a note of the character given to the man, of the cause of discharge, and of his intended address. Get ready all the vouchers required for his final settlement. (See next par.) If the man is only attached to you, write to his own battery to inform them, and to call on them to state in detail all the articles that he ought to give up, whether of clothing or accoutrements. Make certain now that he has no claim for injuries received in the service; if he has, report the fact at once. (This depriving batteries of the men's documents before they are actually discharged is not a good system, and often causes crimes to be overlooked.) The man's clothing and arms should now be carefully examined, and any damage charged for. Requisition on the Clothing Department is now made for a suit of plain clothes for the man, or for an allowance instead thereof.

57. Gunner Emmett comes in for discharge, having given up his arms accoutrements, and leggings. You enter in his pocket ledger the cause, date, place, and his character, signing the entry; also the entry that he is clear on that date in his accounts. His deferred pay is entered in his pocket ledger and signed by you. He reads over and signs his ledger sheet, receives from you the cash due, and signs for it in your cash book. He also receives any savings bank deposit (see par. 58), and signs for it; except it is a gratuity, for payment of which you require special authority. Remember that every item for which he is receiving money should be entered separately and in detail in his ledger sheet, so that if any voucher is afterwards lost you can always prove payment. His name disappears from all books, as in the case of a transfer. The Pay-Serjeant takes in his clothing, and enters it in the clothing ledger, and gets any special receipts, such as lodging allowance, &c. The man has yet to sign the voucher for marching allowance (W.O. Form 84), gratuity for badges if allowed (W.O. Form 157), compensation clothing (W.O. Form 604), allowance plain clothes, if granted. He has already received from the Pay-Serjeant a suit of plain clothes; or if he has provided his own, he and you both sign W.O. Form 279. You fill in on his parchment certificate the amount of his travelling allowance. As soon as he is gone you send off to the Adjutant W.O. Form 559, if he is discharged medically unfit or to pension, and complete the entry in your rough casualty book, taking care that his address is copied therein. His battery documents ought now to go in, but probably have already been called for. This casualty affects your ledger, subdivision pay book, register of arms, register of great coats, clothing ledger, savings bank ledger, certificate book, size roll and married roll, morning state, weekly increase, weekly duty state,

monthly brigade and district returns, casualty return, pay list, and ration book.

58. Gunner Nichol comes in to make a savings bank deposit. You receive it, and enter and sign for it in your cash book, savings bank ledger, and Savings Bank Form No. 2 (in duplicate), and his pocket ledger. It is also entered in his ledger sheet. If he makes a withdrawal, it is he that signs all these.

59. Gunner Wilton comes in to get a pair of socks, accompanied, whenever possible, by the N.C. officer in charge of his subdivision. The issue is entered in the necessaries ledger (par. 24), and in some batteries signed for. The issue is also noted in his ledger sheet.

60. Gunner Young comes in to get an advance of pay. Signs for it in your cash book, after receiving it. The advance is at once noted in his ledger sheet.

61. Corporal Jackson, who is to be attached to your battery for rations, not for pay, for some days, while waiting to give evidence, reports his arrival. His name is at once entered by the Pay-Serjeant in W.O. Form 102, so that his rations can be accounted for; otherwise you will appear to have overdrawn so many rations—that is, there will be an excess of number of rations drawn over number of days pay that you are entitled to draw. His name is also entered in the ration book and in a mess book.

62. Corporal Williams, who has been attached in the same manner to you, reports himself before departure. He signs for any advances he has received, and is examined to see that he takes away his own carbine and sword. As soon as he has gone, W.O. Form 102, for his rations, is sent to his battery, and the date on which it ought to be received back is entered in the rough diary. His name is struck out of the ration and the mess books.

63. Now observe that in all this you have not done a stroke of unneccessary work; every entry must have been made sooner or later, while by making them at once, and in books, instead of pieces of paper, you have all the work fully and permanently recorded, and are not obliged to start afresh with every change of assistants. You are not working a private business, but a machine that must be ready to be placed in other hands at any moment. Remember, however, that this system requires a real use of the books, otherwise you will soon find that your clerks have been trusting to notes on scraps of paper, the regular reason being, "I wanted to keep the books clean," which is not at all what is required; what you want is, to keep the books up to date.

Monthly Work.

64. We now come to the work at the end of the month. The punishment return has only the two or three last entries to be checked by you. Before signing it you compare it with the rough casualty book, and the returns of fines, of deprivation of pay, and of forfeiture of good conduct pay, and the court-martial return, to see that all agree; when all these can be signed.

65. The monthly district and brigade returns are also up to date, and are

quickly checked by the previous returns, the casualty return partially checking the brigade return.

66. The ledger is now ready. The ordinary checking consists in simply and rapidly running over each page, checking the additions, and seeing that the balances for the last month have been carried down, and that there are no obvious errors. Thus, there must be something wrong or omitted in two charges in the same month (January), 29 days messing, 3 days hospital. Less than two hours spent in this way will often give good results. But to really check the ledger a good many documents are required, and a beginner should certainly use them. The pay books give the pay issued, and it is a pity that we cannot use a regular pay book, to show the amounts for each man at the end of the month. I myself believe that, in a garrison battery, it would be easier to pay each man singly and directly on his ledger sheet, making him sign then for it; there is just room. This would give a little more trouble to the Pay-Serjeant on pay days, but would save much work and calculation in preparing for pay.

67. Now, supposing the pay is rightly entered in the ledger, you require the following documents to check the accounts:—

Hospital stoppage return.
Return of mulct pay.
" fines.
Punishment return.
Casualty return.
Necessaries ledger.
Tailor's bill.
Shoemaker's bill.
Marking necessaries list.
Family stoppage roll.
Subscription lists (cricket, &c.)
Lists of warrants (if any) received by Paymaster, recoverable from men.
Form 97, or No. 1 Reports, received from Paymaster, for transfers.
Cell return.

This list may seem large, but it really is rapidly run through. You take the ledger, the Pay-Serjeant the vouchers, and he reads them to you in succession; or you can do this only for the first three on the list, simply referring to the others as you come to any charge, and ticking it off in the list. I do not mean to say that this is necessary to be always done by you—you may find everything right; but it is certainly advisable to try it till you can do it quickly. If you have inaccurate clerks, you will soon find the ledger sheets get confused, and you will understand the strength of some of the reasons given in the introduction against the complicated system of cross-totalling.

Checking the Casualty Return.

68. Next comes the checking of the casualty return. You take the fair return, the Serjeant-Major, or his clerk, the rough casualty book, and he reads out to you all entries. This insures your having all of them down. You will remember that the rough casualty book has been already brought into agreement with the punishment, court-martial, deprivation of pay, fines, and other returns. Next, the Serjeant-Major takes the attestations, and reads to you the age and date of each man's attestation, as you go through your entries in regular order, and he also reads the entry on the attestation that ought to agree with that you are looking at. Now is the time to enter any casualties you have omitted on the attestations. Then you have to see that the duplicate return and the fair copy in the book all agree. It is as

well to also compare any entries in the defaulter sheets affecting the casualties.

69. The vouchers for grants and restorations of good-conduct pay should have been checked by you some days previously. To be able to do this, about once in six months make out a list of what men, supposing they get no regimental entries, will get badges during the ensuing six months. You take the attestations, the Serjeant-Major the defaulter sheets, and you quickly run through the battery. This takes less time than you would expect, as so many men can be passed over at a glance. A man just granted or restored, or who has just forfeited a badge, is at once passed over; while a host of others will be struck out by a reference to the defaulter book. Eventually you get a list showing the date of each expected grant or restoration; and this is pasted inside the portfolio that holds the attestations.

Restorations of service should also be noted at the same time; they are very easily overlooked; also the dates on which men will become qualified to be recommended for the good-conduct medal, or complete 6 or 12 years' service. All this prevents hurry and confusion at the end of the month.

Checking the Pay List.

70. The pay list requires to be checked by most of the vouchers used in checking the ledger, as well as the ration return—in fact the ledger itself ought to be the best check on the pay list. What really confuses the pay list are all the annoying little charges, "ship rations," &c. If a man simply got or did not get his pay, all would be right; and it is a pity that army reformers do not try to get rid of all the varying stoppages, and the little calculations that they necessitate. What also is required is an order that all hospital stoppage rolls, No. 1 Reports, cell returns, notifications of issue of warrants to men on furlough, and W.O. Forms 102 (rations issued to men by batteries to which the men do not belong) are to go direct to the Major, not to the Paymaster; also, a regulation that whenever a Paymaster or Government Department accepts a document with list of vouchers attached, they must, if they do not protest within a month, be held to have received the vouchers. Practically, the last pay list, with the casualty book to explain differences, will form the quickest way of checking the pay list, always remembering that the good-conduct pay claims inserted in say January's casualty return will not appear in the pay list till February, as the vouchers will not be passed till then.

71. The balance in the pay list should only be at first struck in pencil, and you then turn to your balance sheet, transfer to it the pay list balance, and strike the balance then. All the other items can have been entered some time before, and there ought to be little uncertainty about them. If anything is wrong, the balance sheet will at once show it. Probably you will find some special payment or receipt that has not been carried out into the sheet. There is little danger of anything being wrong if the balance is the same as that of the last month; and if that is the case the pay list can be closed immediately.

Pay Tickets.

72. One of the great difficulties with a garrison battery is to get all the men to do anything—say sign books—on any particular day. There are

generally a number of employed men who, in conjunction with their employers, have many reasons ready to show that they cannot attend at any hour of the day and night; and whatever care is taken, some men will, when too late, be found to have escaped. It is, for example, especially difficult to carry out the annual checking of next of kin, issue of clothing, and of great coats. A simple plan was introduced into a battery that practically had all its men either employed or on some duty every day of the year, even on muster day. Due notice having been given, say of signing books, Saturday was chosen for pay day, and the Nos. 1 received the pay for their subdivisions as usual, but were sent to their own rooms with orders not to pay any man without a ticket. Each man, as he signed his accounts in the office, received, on production of his pocket ledger, a pay ticket (a small piece of tin with the number of the battery marked on it), and he then went to his N.C. officer to receive his pay and to give up his ticket. Considerable latitude was given, under the peculiar circumstances of the battery, as to the time the men signed, so that they could attend before or after dinner at their own arrangement and convenience. At first the N.C. officers returned, at the time fixed for them, with few tickets, and most of the pay unissued; but this soon ceased. The employers of the men could not complain, as they had to allow their men to come in for dinner; and the old excuses disappeared. The N.C. officers coming in with their pay books had to give up a ticket for each man shown as paid. The money not issued was returned, and the names of men not paid, copied into the rough diary, formed a handy list of those that had yet to be seen. I can strongly recommend this plan.

73. Once a month or quarter go over all the printed orders you receive—General Orders, Army Circulars, &c.—and see that wherever they alter a former order the alteration is either made in the original order or else that a clear reference to the change is made in the margin. The Queen's Regulations and the Pay Warrants soon become worse than useless if this is not done. There is no doubt but that a biennial or triennial issue of all the working regulations, Queen's, pay, and clothing, so that all circulars previous to the last issue might be destroyed, would be a reform easily carried out, and a much-prized boon to officers. The unfortunate present tendency to issue important instructions on clothing, &c., in manuscript might be stopped with great advantage.

Taking over a Battery.

74. This is a large subject, on which only a few notes are here offered. When the officer giving over the battery is to remain in the service, the work is comparatively easy, as the new Major starts fresh; all claims not stated in the balance sheet being dealt with by the former commander. Otherwise, this is very difficult work. The balance sheet can be first checked according to the information given in pars. 15 to 20. Next, the last received audits of the pay list, savings bank, clothing, and equipment ledgers should be produced. Then enquiry should be made as to any sales or issues of necessaries and clothing, to see that these are duly accounted for. Stock is taken of all stores, clothing, &c., in hand, to see if they agree with the books. The savings bank ledger can only be checked by the actual attendance of all depositors within the year, with their pocket ledgers. The arms and equipment are inspected in detail, an armourer being present, as well as a collar-maker or proper tradesman.

Date.	From whom received.	Payments. On what account.	Amount.	Signature.
		o 31 Dec. 78:—	£ s. d.	
		s. d. £ s. d. £ d.		
1	Major Phipps, R.A. ...	eer 2 0 | No. 5 Mess 1 17 7 Beer 4 10		
		" 2 0 | " 6 " 1 14 1 " 7 3		
		" 7 6 | " 7 " 2 2 11 " 9 3		
6	No. 1428, Gr. J. Haldon	" 4 0 | " 8 " 2 15 1 " 4 1		
		15 6 8 16 11 15 6		
7	No. 72, Serjt. R. Jones	17 6 7 2 0 11	19 7 6	See filed receipt.
8	Paymaster-General ...	.....	0 16 0	J. Clements.
8	Officer Comdg. 6th Bde., R.A.	.....	0 10 0	J. Older.
		s. d.		
		chool,.....Dec. 78..... 0 8		
		Guard Room " 1 4		
29	Paymaster-General ...	..... " 4 5		
			0 6 5	See filed receipt.
		£ s. d. £ s. d.		
		n. 79... 6 7 0 ... Washing ... 0 7 9	6 14 9	J. Young.
		... 7 19 6 ... " ... 0 8 6	8 8 0	J. O'Callaghan.
		... 6 19 0 ... " ... 0 7 6	7 6 6	J. Nelson.
		... 5 17 6 ... " ... 0 7 7	6 5 1	P. Mack.
		... 6 4 0 ... " ... 0 7 0	6 11 0	G. Jackman.
		... 7 6 0 ... " ... 0 9 6	7 15 6	H. Dundas.
		... 7 19 6 ... " ... 0 9 1	8 8 7	R. Jones.
		... 10 5 0 ... " ... 0 10 9	10 15 9	H. Hamilton.
		58 17 6 3 7 8		£62 5 2
		ital	0 1 0	See ledger.
		£ s. d.		
		r. J. Batten 1 4 2		
		" A. Thomson..... 0 4 10		
		1 9 0		
		Gr. T. Maher 0 5 4	1 3 8	See filed receipt.
		rned	0 7 0	S. Tollett.
		.....	0 15 0	W. Bell.
		* * *		
		Taylor, Jan. 79, 7s. 7d., P.O. Order 2d. ...	0 7 9	See filed receipt.
		9	2 18 0	See fund book.
		.....	7 16 11	"
		.....	3 19 8	"
		.....	0 8 9	W. Hand.
		.....	0 11 7	T. Shannon.
		.....	3 14 11	R. Phipps, Major.
		.....	182 3 5	R. Phipps, Major.
		£	539 18 11	

R. PHIPPS, Major R.A.,

Comdg. No. 14 Batt., 11th Bde., R.A.

APPENDIX A.

CASH ACCOUNT OF No. 14, MAJOR PHIPPS' BATTERY, 11TH BDE., ROYAL ARTILLERY.

January, 1879.

Date.	From whom received.	Receipts. On what account.	Amount. £ s. d.	Signature.
1	Major Phipps, R.A. ...	Cash in hand, 31 Dec. 78.....	198 6 7	R. Phipps, Major.
6	No. 1428, Gr. J. Haldon	Savings Bank Deposit	1 0 0	J. Clark, Capt.
7	No. 72, Serjt. R. Jones	Return of pay of No. 1482, Gr. S. Tollett, abst.	0 7 0	R. Phipps, Major, paid out 8 1 79.
8	Paymaster-General ...	2nd instalment, Jan. 79 pay	170 0 0	R. Phipps, Major.
8	Officer Comdg. 6th Bde., R.A.	Ledger debt, Nov. 78, No. 41, Gr. T. Maher	0 5 4	J. Clark, Capt.
29	Paymaster-General ...	1st instalment, Feb. 79 pay.....	170 0 0	R. Phipps, Major.
		£	539 18 11	

Date.	To whom paid.	Payments. On what account.	Amount. £ s. d.	Signature.
2	R.A. Canteen, Woolwich	Bills, Groceries, Beer, &c., to 31 Dec. 78:—		
		No. 1 Mess £2 5 6 Beer 2 0 — No. 5 Mess £1 17 7 Beer £4 10		
		" 2 " 2 14 11 " 2 0 — " 6 " 1 14 1 " 7 3		
		" 3 " 1 17 8 " 7 6 — " 7 " 2 2 11 " 9 3		
		" 4 " 1 18 10 " 4 0 — " 8 " 2 15 1 " 4 1		
		8 16 11 15 6 — 8 16 11 15 6		
		17 6 7 £2 0 11	19 7 6	See filed receipt.
2	Mr. J. Clements	Milk Bills, 24 to 31 Dec. 78	0 16 0	J. Clements.
3	No. 1572, Gr. J. Older	Cash advance	0 10 0	J. Older.
4	Qr.-Master 1st Bde. R.A.	Share of barrack damage, School,.....Dec. 78..... s. d. 0 8		
		" " Guard Room " 1 4		
		Glass bill ..... " 4 5	0 6 5	See filed receipt.
7	Br. Young	Pay of No. 1 Sub., 1 to 7 Jan. 79... £6 7 0 ... Washing ... £0 7 9	6 14 9	J. Young.
7	" O'Callaghan	" 2 " " ... 7 19 6 ... " ... 0 8 6	8 8 0	J. O'Callaghan.
7	Corpl. Nelson	" 3 " " ... 6 19 0 ... " ... 0 7 6	7 6 6	J. Nelson.
7	Act. Br. Mack.....	" 4 " " ... 5 17 6 ... " ... 0 7 7	6 5 1	P. Mack.
7	Corpl. Jackman	" 5 " " ... 6 4 0 ... " ... 0 7 0	6 11 0	G. Jackman.
7	Corpl. Dundas.....	" 6 " " ... 7 6 0 ... " ... 0 9 6	7 15 6	H. Dundas.
7	Serjt. Jones	" 7 " " ... 7 19 6 ... " ... 0 9 1	8 8 7	R. Jones.
7	Corpl. Hamilton	" 8 " " ... 10 5 0 ... " ... 0 10 9	10 15 9	H. Hamilton.
		58 17 6 3 7 8		£62 5 2
8	Br. Wall	Tobacco and stamps in Hospital	0 1 0	See ledger.
8	Officer Comdg. 6 Batt., 22nd Bde., R.A. ...	£ s. d.		
		Credit, Dec. 78, No. 1682, Gr. J. Batten 1 4 2		
		" " " 303, " A. Thomson..... 0 4 10		
		1 9 0		
		Less debt, Dec. 78, No. 41, Gr. T. Maher 0 5 4	1 3 8	See filed receipt.
8	No. 1482, Gr. S. Tollett	Pay due 8 Jan. 79, but returned	0 7 0	S. Tollett.
8	No. 1399, Gr. W. Bell	Savings Bank withdrawal	0 15 0	W. Bell.
		* * * * *		
29	Mrs. E. Taylor	Stoppages, No. 1712, Gr. J. Taylor, Jan. 79, 7s. 7d., P.O. Order 2d. ...	0 7 9	See filed receipt.
31	Battery Tailors' Shop...	Tailor's Bill..... Jan. 79	2 18 0	See fund book.
31	" Shoemakers' " ...	Boot " "	7 16 11	"
31	" Necessaries Fund	Necessaries sold "	3 19 8	"
31	No. 26, Gr. W. Hand ..	Marking necessaries "	0 8 9	W. Hand.
	No. 98, Gr. T. Shannon	Hair cutting "	0 11 7	T. Shannon.
31	Major R. Phipps.....	Forage allowance "	3 14 11	R. Phipps, Major.
		Cash in hand	182 3 5	R. Phipps, Major.
		£	539 18 11	

R. PHIPPS, Major R.A.,

Comdg. No. 14 Batt., 11th Bde., R.A.

APPENDIX B.

BALANCE SHEET OF No. 14, MAJOR PHIPPS' BATTERY, 11TH BDE., ROYAL ARTILLERY.

31 December, 1878.

From whom due.	Cr. On what account.	Amount.		To whom due.	Dr. On what account.	Amount.	
		£ s. d.				£ s. d.	
Major Phipps	Cash in hand, 31 Dec. 78	198 6 7		Men of battery	Credits in ledger.....	4 5 8	
				" "	" mess books	0 3 6	
				Paymaster	1st instalment, Jan. 79 pay ...	170 0 0	
				"	Balance Dr. Dec. 78 pay list...	8 9 4	
Men of battery	Debts in ledger	7 4 3					
"	" mess books	0 2 4		R.A.Cantn.,Woolwich	Bills, 24 to 31 Dec. 78	19 7 6	Pd. 2 1 79
				Mr. Clements	Milk bills, 24 to 31 Dec. 78 ...	0 16 0	Pd. 2 1 79
						s. d.	
				Qr.-Mr. 1st Bde., R.A.	Barrack damage, School...	0 8	
					" Guard room	1 4	
					Glass bill	4 5	
Clothing Department	Compensation, No. 67, Gr. J. Counts (paid on discharge, not yet passed)	0 12 0	Drawn in Jan. pay list.			0 6 5	Pd. 4 1 79
						£ s. d.	
				Officer Com. 6/22 R.A.	Cred. Dec. 78, No. 1682, Gr. J. Batten	1 4 2	
Officer Com. 6/22 R.A.	Debt, No. 41, Gr. T. Maher...	0 5 4	Rec. 8 1 79, from credits due.		Do., No. 303, Gr. C. Thomson	0 4 10	
						1 9 0	Pd. 8 1 79
				Mrs. Allan	Stoppage, No. 59, Gr. R. Allan, Dec. 78.....	0 7 9	
					Balance credit	1 5 4	
	£	206 10 6			£	206 10 6	

R. PHIPPS, Major R.A.,

Comdg. No. 14 Batt., 11th Bde., R.A.

ON THE QUESTION WHETHER ANY DEVELOPMENT OF THE MATÉRIEL OF FIELD ARTILLERY IS NECESSITATED BY THE GENERAL ADOPTION OF ENTRENCHMENTS ON THE FIELD OF BATTLE; AND IF SO, ON THE DIRECTION SUCH DEVELOPMENT SHOULD TAKE.

BY

LIEUT. F. M. GOOLD-ADAMS, R.A.

(*The R.A. Institution Gold Medal Prize Essay, 1879.*)

"Manibus victoria dextris."

Comparative falling off in effect of rifled artillery.

1. Colonel (now General) Hamley, in his "Operations of War," comes to the conclusion that the effect of the smooth-bore field gun of former days on the field of battle was greater in comparison with that of the infantry arm then used than is the effect produced by rifled guns relatively to that of the breech-loading rifle. He gives the following reasons, viz. :—

(1) The power of infantry fire has developed to a much greater extent than has that of artillery at close range.

(2) The opportunities of effective artillery fire have diminished as range and accuracy (*i.e.* of the rifle) have increased.

There can be no doubt as to the soundness of these arguments, at any rate until the introduction of our present field ordnance. No one can read the campaigns of Napoleon I. without recognising the decisive effects produced by artillery on the field of battle—as at Eylau, Friedland, and Aspern; but he will also be struck by the wholesale manner in which it always fell into the hands of a victor on account of its want of mobility. We may say, then, that artillery is not so powerful comparatively as it used to be.

Causes of change and remedy are the questions to be answered; necessity for artillery not lessened.

2. The questions at once arise :—How has this change come about? How can it be remedied? These questions we propose in this paper to discuss, as the answers will enable us to form some idea as to what the artillery of the future should be able to do. At the same time, we must remember that although Colonel Hamley's deduction as to the comparative effect of the two arms, artillery and infantry, may be true, the necessity for a powerful force of artillery has become of more essential importance than ever. The very fact that infantry fire has become so powerful that a direct attack on infantry in a good position is impossible without the co-operation of artillery, whereas in former times such was not the case, has rendered the presence of artillery on the field of battle a matter of more absolute necessity. Moreover, it

must be present, to perform its work effectually, in sufficient force to hold in check, if not altogether to subdue, the enemy's artillery. The necessity, then, for its existence has in no way diminished.

Causes of change of relative power.

3. Let us now examine the causes which have led to infantry fire having been developed to such an extent as to have reversed the relative power of the two arms at close range. In former times, infantry fire was certainly not effective at more than 300 yds. At this range the case fire of the S.B. gun was most deadly, and could certainly overwhelm the fire of the infantry. Now, infantry fire begins to be effective at 800 yds., and can be felt much further. Case fire of rifled guns, up to the present time, has certainly been less effective than that of the smooth-bores which preceded them, and at 800 yds. the fire of segment from an Armstrong 12-pr. (service B.L.), or even shrapnel from a 9-pr. R.M.L., cannot compete with S.B. case at the ranges at which it was used. Thus, then, the range of infantry fire has greatly increased, while that of artillery's most destructive projectile has rather diminished. We speak, of course, of guns actually in our service, and not of any which may be introduced hereafter. This loss of efficiency of case fire is due to two causes, viz. —(1) The very low proportionate charges fired by rifled guns, as compared with smooth-bores. This is fatal to good case, which requires a high muzzle velocity. (2) A considerable proportion of the weight of the projectile is taken up by segmental linings, &c., to prevent a spin being given by the rifling, which would cause the bullets to scatter so much as to seriously impair the effect. The capacity for bullets is thus much reduced. In "Treatise on Ammunition," 1874, p. 126, we see that in some instances nearly half the total weight is thus lost. In old S.B. case the envelope generally weighed from $\frac{1}{8}$ to $\frac{1}{9}$ of the whole.

Again, infantry fire has increased enormously in rapidity and ease of fire; also—what is perhaps of more importance—modern rifles can be loaded by a man lying down, thus exposing a very small mark to fire at. Moreover, the increased range of rifle fire gives the infantryman a much greater chance of obtaining cover, and thus of protecting himself from the artillery. On the other hand, the fire of artillery's most deadly weapon at ordinary ranges—the shrapnel—is much slower than was the case fire of S.B. guns. The long time taken to bore and fix a time fuze of the present pattern (which sort of fuze gives better results than percussion), materially weakens artillery fire at decisive moments.

What we must do to remedy this state of things.

4. The problem, then, to be solved, in order to re-establish the preponderance of artillery fire at close ranges, may be stated thus:—Case fire to be much more destructive than formerly; shrapnel fire at 600 to 800 yds. to be as destructive against modern formations as was S.B. case against a line 2-deep at 300 to 400 yds.

Opportunity for effective artillery fire not frequent.

5. With regard to Colonel Hamley's second argument—viz., that the opportunities of effective artillery have decreased—the state of affairs is not so adverse to the gun as might be thought at first. True, the targets exposed are not so inviting, but the range during

which bodies of hostile troops must move more or less exposed to fire has increased enormously; also, we are now furnished with a very deadly projectile—shrapnel or kindred shells—at all ranges; whereas, in former times, the moment case fire ceased to be available, solid shot, whose effect was chiefly moral, had to be employed. It is true that occasionally use was made of shrapnel from S.B. guns; but the great loss of velocity from retardation and the irregular effect of the bursting charge, together with the imperfection of the fuzes used, prevented the general introduction of this nature of projectile.

We think there are few who would not prefer to be fired at in line by a battery of S.B. guns firing solid shot at 600 yds., to moving in modern attack formation under the shrapnel fire of guns of the latest pattern at 1300 yds.

Falling off in effect in action compared to peace practice.

6. Again, there is no doubt that hitherto the effects produced by rifled artillery on the field of battle have not come up to what might have been expected from its performances on the practice ground. The same may be said of small-arms. If infantry could shoot as well in action as at practice, one battalion would probably be at least as effective as ten are now; common causes leading to a common falling off in the effects of both arms in action, compared with peace performances. Colonel Hamley has omitted this consideration from the comparison between them.

Probable that more may be done for artillery than infantry in the way of getting better comparative effect in action.

7. But we think that we shall see, as we go on, that many of the causes producing bad practice in action may be eliminated or reduced in magnitude, in the case of the artillery, whereas it appears to be well nigh impossible to effect much further improvement in infantry fire beyond what may be effected by better training of the men. This dictum, however, cannot be considered as final, but only true as far as our present knowledge extends.

Causes of bad performance of artillery in action.

8. We may say, then, that the causes which have led to the generally indifferent performances of rifled guns on the field of battle, compared with effects obtained in peace time, are—

(1) Bad handling, or false tactics.
(2) Want of skill and acquaintance with their weapon on the part of officers and men fighting it.
(3) Want of power on the part of the gun itself, and want of the necessary appliances for developing whatever power existed —such as range-finders, &c.

It is with regard to this last point that we propose to speak. The consideration of it leads us back at once to the point whence we started—viz., that the comparative power of artillery has declined. Want of power in the individual gun has been the chief cause of this change. Infantry fire has improved in effect far more than artillery; but the power of the individual man limits the development of the small-arm. As far as we can see at present, a limit has been reached in the case of the Martini-Henry; witness the great complaints made,

on its introduction into the service, of the severity of the recoil. On the other hand, artillery appears only in its infancy. No power of man to bear recoil arrests its progress. Every advancement in the mechanical arts should aid the development of its power. Steel, better powder and fuzes, improved construction of shells and carriages, breaks to reduce recoil, gun-cotton or a similar powerful explosive as a burster for shells, &c.—all may be enlisted into its service.

Thus it seems that, for the present, infantry fire has reached its limit, while that of artillery, even in the immediate future, is, we trust, far from being attained. Infantry fire depends chiefly for effect on flatness of trajectory; artillery combines, or should combine, a greatly extended flatness of trajectory with power of shell both against *matériel* and men.

The first two causes of indifferent performance given above are common to both arms, and we do not propose to consider them here; but few will doubt that they have existed, and do exist, in most armies to an extent that can hardly be credited.

Remedy for existing state of the question.

9. Having, then, cursorily examined the causes which have led not only to the change in the relative powers of artillery and infantry, but also those which, in common to both arms, produce such a diminution in effect in action, we pass on to consider how the chief of the defects noticed above—viz., want of power—can be remedied in case of the artillery.

We pointed out above the necessary conditions for restoring their ancient preponderance to the guns—viz., the development of power of case and shrapnel; we may add, also, the adoption of some movable bullet-proof screen to accompany artillery in the field and protect the gunners from infantry fire at close range, as proposed by Colonel C. B. Brackenbury. This would also be of incalculable advantage in protecting the gunners from shrapnel. Moreover, in order to obtain better comparative results in action, we must remedy that want of power so noticeable in rifled ordnance hitherto.

Want of power—*i.e.* velocity—at all ranges the great defect of rifled ordnance hitherto.

10. Rifled field guns were for a long time after their introduction, and even now in the minds of many people are, only required to be good target guns; that is to say, that accuracy of shooting at tolerably long ranges is considered the one thing needful. This idea, we are happy to say, is fast dying out, but it has been fearfully prevalent. The muzzle velocities of most rifled guns—in fact, up till quite lately we might say of all—have been very low, and consequently the muzzle energies small. In this respect they resemble many sporting rifles, which would make good practice at a target at a known range, but unsuited, from their curved trajectory and want of smashing power, for firing at an animal moving rapidly, and consequently varying the range quickly, or one whose dangerous strength rendered it necessary that the first wound should disable. This has been remedied by the introduction of the express rifle. We must follow in the same path. Early rifled guns shot well at long known ranges, but from their low muzzle velocities their case fire was contemptible; and from this cause,

combined with their makers' insufficient appreciation of the value of a heavy shell with small bore, their long-range fire was that of a howitzer rather than of a gun. The Germans clearly understood this in 1870, and their constant endeavours to get to close range show that they appreciated the only method of even partially counteracting this weakness. On the other hand, the want of self-defensive power on the part of the guns at close range rendered this course a peculiarly dangerous one, and it was only by the skill and valour of the gunners, and the large number of pieces which were generally massed, that these tactics were carried out to a successful issue.

The great curvature of the trajectories rendered a very exact knowledge of the range essential. This, under the conditions of battle and without range-finders, was often impossible, owing to the difficulty of judging where the shells burst. Moreover, this evil of curved trajectories was aggravated by the want of a good man-killing projectile and by the almost sole use of percussion fuzes. England certainly for a long time occupied the best position with regard to projectiles; the Armstrong segment being a better shell for field purposes than any percussion shell used in Europe up to 1870. But it was a compromise, and, like many compromises, was not a great success. Introduced to act as and supersede common shell, shrapnel, and case, it was soon found necessary to re-introduce these latter projectiles. When fired at targets representing troops in close formation, at known and tolerably close range, it did well, but as conditions of practice were departed from, and it was fired at unknown and varying ranges, over broken ground and against troops in loose formation—in fact, the more nearly conditions of war were approached—the further it fell behind its rival, the shrapnel. In respect of projectiles, however, the rest of Europe was generally further behind. Even in 1870 the Germans had hardly anything but common shell and percussion fuzes. This shell broke up, it is true, into more fragments than our common, but not into nearly as many as our segment.

Want of good shells and fuzes.

Thus, with a very high trajectory, the naturally local action of a percussion shell was rendered more local, and in soft ground or against the face of a hill sloping towards the guns, the shells were almost buried when they exploded, and those that did hit the object against which they were directed did scarcely any more damage than solid shot would have done.

The French did, indeed, introduce shrapnel and time fuzes, but the guns which fired them were of very large calibre in proportion to the weight of the shell, which were thus much retarded in flight; the muzzle velocities were very low, and the fuze could only be set to burst the shell at, at most, five different ranges. A certain amount of effect might have been produced had the fuzes been good, but under the circumstances it is not wonderful that the effect produced by their fire was trifling. As we said above, the want of range-finders was especially detrimental to guns like the French and German of 1870, the high trajectories of which rendered it very desirable to know the range exactly. We thus arrive at the state of affairs at the date of introduction of our present M.L. field guns and the close of the Franco-German war in France.

French shrapnel before 1870.

We must accept the past as a guide for the future.

11. It may be said that it is now easy to point out the faults of a bygone artillery, and that it was as good as the state of the mechanical arts admitted. Quite so; but it is only by reflecting on its faults that we can be guided into adopting the proper methods of making our future field artillery as powerful as it should be. Moreover, many, even of those who should know better, do not recognise the importance of high velocity and flat trajectory, and the writer has heard it said more than once, "We don't want high velocity for field guns; 1200 f.s. or so is quite sufficient;" or again, "A 12-lb. shell will do everything we want in the field; we don't see the necessity for a heavier shell." Those who entertain such ideas cannot have the good of their service at heart, nor can they wish—as every artilleryman should do—to make it the principal arm in action. We are told so often, officially and otherwise, that the infantry is the principal arm in action under all circumstances, that it has been and will be so, that at last many of us begin to believe this to be an unalterable truth. It is exactly the reverse of what should be the case. That it is so now, no one can doubt; but that it will always continue to be so, the progress of artillery during the last year or two renders quite open to question.

We must make every effort to improve. It would be a highly desirable achievement, if we could by some means do it, to have a field gun which could throw a 50 or 100-lb. shell with 1600 or 1700 f.s. Of course this is an impossibility, but it would be a very splendid result. We merely make this illustration to exemplify our meaning—viz., that no amount of progress that we can make is unnecessary or not absolutely required. The unanimous testimony of even unprofessional observers of actual fighting is, that the weak point of rifled guns hitherto has been the great angles of descent of their shells at any but very short ranges. We remember being taught that one great advantage possessed by rifled guns over smooth-bore was that a great saving of powder was effected. This was, perhaps, the strongest condemnation that could have been put in the same number of words. We must have flat trajectories in the field artillery of the future.

Curved trajectories the great evil of artillery.

Present R.M.L. field ordnance.

12. We now come to the guns (9 and 16-prs.) at present in our service, and in speaking of them in must be understood we in no way wish to cast diseredit on their designers. They were, at the time of their introduction, the most powerful field guns in Europe, and were great improvements (especially the 16-prs.) on the guns which they superseded.

The general introduction of shrapnel, time fuzes, and higher velocities made them much more generally formidable; but still the old faults of too large bore in proportion to the weight of the shell, and of comparatively low velocity remain. The system of rifling militates against the production of a good shrapnel, and the time fuzes, from the long time required for their preparation, &c., are unsuited for rapid fire or quickly varying ranges.

Requirements of artillery.

13. In an article which appeared in the "Times" soon after the first manœuvres, when the present guns had been lately introduced,

there are some remarks on field guns well worthy of attention, and which display a foresight and acquaintance with the requirements of artillery fit to take its proper position in action which must do infinite credit to the writer.

He first quotes Prince Hohenlohe, where the latter says, "We should not fire at masses of troops beyond 3000 paces (2,500 yds.), nor approach unbroken infantry within 800." The writer of the article then says, "Is this to be taken as absolute? Cannot we advance a step or two beyond these restrictive rules? Cannot we get guns which will range further without such a high curvature of the shells' path? Cannot we estimate distances accurately at long range, and find a powder more proof against the influence of the weather than that of the Prussians?" (This question arose from Prince Hohenlohe saying that the weather had such an effect on the Prussian powder). "At short ranges, cannot we manage to protect the gunners a little and the horses entirely against infantry fire in action, so that there may be no more talk of artillery always running away from men armed with an inferior weapon? Cannot we devise projectiles more deadly at close range than common case shot?" The writer then answers these questions, to a certain extent, himself, by saying that what tacticians want are, long-range guns with *a flat trajectory and high velocity*, simple and good range-finders, good powder of uniform quality, accurate range-tables, and some protection to men and horses.

These considerations to a great extent determine the requirements of the Field Artillery of the Future. With regard to protection for men and horses, the ground will often afford some; often, however, it will not, and never will cover thus afforded compete with that to be obtained from movable bullet-proof screens, as proposed by Colonel Brackenbury. The adoption of some good pattern, combined with greatly increased power, of gun will quite revolutionise artillery tactics. A great protection, too, lies in great destructive power on the part of the gun: the more powerful it is, the quicker will the enemy be checked and his fire subdued. It is evident that a very powerful gun will beat off an attack to which a less powerful one would have succumbed, and would repulse an attack which would have failed even against a less powerful weapon, in less time, with more loss to the enemy and less to itself.

14. Consequently, with a more powerful weapon, offensive action at closer range is attended with less risk and with a greater chance of a successful issue. Result of increase of power.

15. The fact is that until we possess weapons of such power of shell and flatness of trajectory that a large per-centage of rounds at moderate ranges are effective, even when those ranges are uncertain and vary, until then we shall not produce effects commensurate with the complication, expense, and difficulty of transport which an artillery force entails. We can only produce these effects by the shells, when burst, covering a very large depth of dangerous ground, and so neutralising, to a certain extent, errors in the estimation of range, in Necessity for guns of great power.

setting the fuze, and in laying. It is most important, too, that at an early period of the attack the bullets of the shrapnel should cover sufficient ground to embrace both skirmishers and supports of the infantry attack formation. The distance between these bodies cannot, in general, be increased beyond 300 yds., at the outside, due regard being paid to facility of reinforcing the front line. At 2000 yds. the shrapnel of the 24-pr. gun hereinafter proposed would cover 340 yds. of ground, burst 20 ft. above plane. Within this range (2000 yds.) a considerable per-centage of casualties would be caused to supports 300 yds. in rear of the skirmishers, the shells bursting from 40 to 50 yds. in front of the latter.

How to increase power.

16. How, then, can we increase the power of the guns? We answer, increase the velocity and weight of the projectiles, and improve the fuzes and projectiles. By this means we shall gain that flatness of trajectory which has been so much insisted on as a necessity in the former part of this paper. Also we must have increase of weight of shell; as since artillery fire, however much improved, can hardly excel the smooth-bore in rapidity of fire, we must depend for increase of effect at short range, to a great extent, on increase of weight of shell.

Nature of guns proposed.

17. We advocate, then, the introduction of guns of the following description. Of course they must only be taken as rough sketches; but it is well to set up a standard of power, and we are convinced it is not beyond the bounds of possibility that the following may be attained, even with our present mechanical skill.

Light Field Gun.

Weight of gun. cwt.	Weight of shell. lbs.	Calibre. ins.	M.V. f.s.	No. of rounds.	Weight of whole. cwt.
7 to 8	15	3	1550	40	34 to 35

Heavy Field Gun.

12	24	3·6	1550 to 1600	30	42

The light gun above described will soon be approached in power by the new 13-pr., but increase in the weight of the shell presents such advantages that it would appear desirable to continue experiments to ascertain if improvements in construction and manufacture of carriages would not permit of such an increase of power.

System of artillery.

18. A system of artillery complete may be divided into four distinct parts—viz., the gun, the carriage, the limber, and the ammunition; and it is in this order that we propose to discuss the subject.

The gun.

19. We proceed then to discuss the question of the gun; and as the heavy one would present the greatest difficulties, we shall confine our remarks to it. If the problem above indicated—that is, to throw a 24-lb. shell with a muzzle velocity of 1600 f.s. from a 12-cwt. gun—had been propounded a few years ago, it would have been regarded as

an impossibility; but there can be little doubt as to the capability of our Gun Factories to produce such a weapon. Improvements in powder, and a better understanding of the conditions of its combustion, have conferred on us to an extraordinary degree the power of obtaining a high muzzle velocity with a small maximum pressure. We have discovered the advantages to be obtained from the use of enlarged powder-chambers, the greatest of which is that we are enabled to use an air-spaced cartridge (say 34 or 35 cub. ins. to the lb., or even more) and yet retain a comparatively short cartridge. We have also discovered the advantage of length of bore; together with the fact that, by having suitable appliances on the gun-carriage, long guns are not so inconvenient to handle in the field as we used to imagine. The much vexed question then arises, Is our gun to be a breech-loader or a muzzle-loader? We decidedly prefer the breech-loader, for the following reasons:— B.L., advantages of.

(1) The B.L. is much more handy to work, especially when very long in the bore.

(2) The B.L. gives more cover to the gun detachment.

(3) The B.L. can now be made almost as simple and quite as strong for practical purposes as the M.L., and there is not that danger of a shell jamming in loading which exists in a M.L. gun to some extent.

(4) With very long shells, such as would be those of the guns above described, the B.L. has the advantage of requiring a less rapid twist to give accurate shooting, on account of its perfect centring; and also some system of rotation, such as by copper rings, can be adopted, which supports the walls of the shell against the setting-up strain caused by discharge. This is especially valuable in the case of the shrapnel shell.

(5) The B.L. system adapts itself more readily to the use of an enlarged powder-chamber.

(6) The old objection that the time fuze cannot be lighted by the flash we regard rather as an advantage; the quickmatch method of lighting leading to irregularities of burning. Cap composition, such as is now used in our B.L. fuzes for detonators, seems to act very certainly and well.

The calibre of the heavy gun above proposed is, we see, no larger than that of the 16-pr., while the shell is half as heavy again. The gain in velocity due to diminished retardation is very great, as we see by the following table:—

Gun.	Calibre.	M.V.	V. 1000 yds.	V. 2000 yds.	V. 3000 yds.	V. 4000 yds.
	ins.	f.s.	f.s.	f.s.	f.s.	f.s.
16-pr.	3·6	1350	1010	867	763	682
24-pr.	3·6	1350	1092	955	867	795
24-pr.	3·6	1600	1268	1042	928	846

Compared with present 16-pr.

We see, then, that the proposed gun has at 4000 yds. a velocity not practically differing from that of the present 16-pr. at 2000 yds. We thus get a very flat trajectory up to 3000 yds., which, however powerful the gun may be, will in general be the limit of range for artillery, as beyond it is only under exceptional circumstances of weather, position, &c., that we can see what we are doing. The angle of descent at 3000 yds. would be about 7°. This means a fall of about 1 ft. in 8; or 6 ft.—the height of a man—would be covered for 16 yds. before graze. The velocity, too, is still high (928 f.s.) Under the same circumstances the 16-pr. has an angle of descent of about 1 ft. in 5, and consequently an object 6 ft. high only covers 10 yds. of ground.

In other words, supposing the guns to shoot equally well, at 3000 yds. the chances of striking an object of given height are nearly 8 to 5 in favour of the 24-pr. A glance at the comparative diagram of shrapnel at 2000 yds. shows that when the shell is burst at 1900 yds., or 100 yds. short of the target, the furthest bullet only ranges 225 yds. from burst to graze in the case of the 16-pr., while it ranges no less than 340 yds. in the case of the 24-pr. The 24-lb. shell is only 20 ft. above the ground at burst; the lowest bullet would strike the ground about 43 yds. nearer the target, with an angle of descent of 11° 20′, about. The 16-pr. shell is 32·5 ft. off the ground when it explodes; its lowest bullet strikes 42 yds. short of the target, 58 from burst, and has an angle of descent of about 14°.

These considerations show what very great advantages are to be obtained from flatness of trajectory. We shall consider more in detail the advantages of the proposed gun in shrapnel fire under the head of Ammunition.

Special points to be observed for the future.

20. What, then, do we advocate as the especial points necessary to be observed in constructing the field guns of the future? We think as follows:—

(1) They must not exceed the present guns in weight.

(2) We must go further than we have done at present in reducing the calibre compared with the weight of the shell; that is to say, retaining our present calibres, or nearly so, we should be prepared to make the shells much heavier. Increased capacity will follow from increased length; advantage being taken of improvement in the material employed to retain sufficient strength to stand the increased setting-up strain due to greater length.

(3) The present muzzle velocities must be largely increased, in order to gain power at close range and that flatness of trajectory which experience proves to be so essential. Attending closely to the principle of small calibre enunciated above, we are enabled to use these high velocities without great waste of power; that is to say, that as we reduce the calibre compared with that of the shell, so does it become more advantageous to fire shells with high velocities. This the following table shows:—

Velocity.	1600 f.s.	1500 f.s.	1400 f.s.	1300 f.s.
	yds.	yds.	yds.	yds.
16-pr. range	166	345	528	731
24 " "	264	541	833	1151

Calibre, 3·6 ins. Both shells fired with same M.V. (1700 f.s.)

(4) In order to obtain this high velocity, so essential to our purpose, without straining too highly the gun, and, what is almost of more importance, the shell, we must employ chambered guns and air-spaced cartridges; the latter to allow us to generate a large volume of gas at low tension, and the former to allow of the cartridges, when so air-spaced, being of moderate length. If air-spaced cartridges are used in guns having no enlarged chambers, their length has to be increased to an inordinate degree. Wave pressures are apt to result, even if the charge be ignited through a forward vent; moreover, the undue elongation of the powder-chamber is so much useful length cut off the gun. The results hitherto attained in this manner (*i.e.*, chambering and air-spacing) are highly satisfactory; but we are undoubtedly only on the verge of an enormous field of enquiry, the thorough exploration of which must be the work of future experiment. The knowledge of the laws of the combustion of gunpowder is being unfolded to us slowly, but we have the consolation of knowing that more has been done in this direction in the last five years than in the preceding five centuries.

(5) Finally, the question of rotation must be satisfactorily worked out. The best method appears to be that adopted in some countries of copper rings with a B.L. gun. This system gives excellent results for accuracy of practice, and supports the walls of the shell.

[Since the above was written, the 6-in. B.L. Armstrong gun has appeared, firing a 70-lb. shell with 2000 f.s., and having only a low pressure on the powder-chamber. It would be quite possible, we imagine, to make a 12-cwt. gun to throw a 20-lb. shell with that velocity; the calibre being about 3·3 ins. Such a gun would indeed realise our hopes. The question would be, how to get a carriage to stand the recoil. For the production of such a weapon and carriage we must live in hope.] Possible that there may be a further increase in velocity.

21. We now come to the most difficult part of the whole question. As we said above, improvements have taken place so quickly in gun manufacture, powder and the way of burning it, rifling, &c., that the gun manufacturer can no doubt make the guns we want, even with less weight than above allowed—viz., 12 cwt. The question arises, Can a carriage be made? A gun very light compared with the weight and velocity of its projectile must cause a very great strain to the carriage; but there appears to be no doubt that a slow-burning powder, although it does not lessen the total amount of work done, provided the muzzle velocity be the same, greatly lessens the maximum pressure on the car- The carriage.

riage, since the gun starts into motion less quickly. Part, of course, of the higher strain caused by quick-burning powder is exerted in destructive effect on the material of the gun, but part is not. There can be no doubt, we think, that gun and projectile obey the same laws, and that a high initial pressure causes the gun to acquire a given velocity of recoil in a shorter time than a lower pressure would do. This we know to be the case with a projectile, as any velocity curve would show us. High pressure in the gun, then, causes a severe strain on the carriage—in fact, inflicts a blow rather than a push. The quicker, of course, a carriage is put into motion, the more severe is the strain on the material composing it. Again, little strain is put on a carriage in checking the recoil compared to what is done by the gun in putting it into motion. The whole system of gun and carriage probably receives its full velocity of recoil before it has moved 2 ins. at most. If, by means of a very powerful break, we bring it up in, say, 4 ft., we only exert a mean pressure of $\frac{1}{24}$ of what it has already undergone in being put into motion.

We mention this fact because it may be thought that the necessity for checking the recoil of a gun of the nature proposed would add greatly to our difficulties. This is really not the case.

Russian field carriage and steel.

22. Fortunately, also, just at this time, when it appears that we shall have to call upon our carriages to bear far greater strains than hitherto, we are aided by improvements in the production of material. Steel will help us to solve the difficulty by supplying a material far stronger within its elastic limits than wrought-iron. Its ultimate tensile strength, too, is much higher. It is not nearly so easily given a permanent set, but recovers its original form after being strained far beyond the elastic limits of wrought-iron. Thus, loss of strength from loss of form, which often necessitates giving wrought-iron greater dimensions and consequent weight than the mere strain put upon it requires, is not nearly so much to be dreaded when steel is our material. The great objections to steel hitherto—viz., the uncertainty and non-uniformity of the metal, even when produced under apparently similar circumstances, and the deterioration caused by the necessary operations of shearing, punching, &c.—appear to have been nearly, if not altogether, overcome.

We are apparently justified, too, in expecting progress in construction. It must be remembered that the art of iron field carriage construction is as yet in its infancy, not being more than ten years old in our service. Moreover, a very ingenious device for reducing the strains borne by field carriages has been found successful in Russia. It has been adopted for service, according to the "Revue d'Artillerie;" 1200 carriages being ordered on this plan for the new 4-pr., and 500 for the new 9-pr.

This device consists in dividing the carriage into two parts. The first consists merely of the trail brackets, with elevating gear, &c., and also an elastic buffer. The second consists of the axletree, wheels, axletree-seats, two tie-bars (one to each axletree-arm), and a collar-bolt passing through a slot cut in the brackets, connecting the rear ends of

the tie-bars together. This collar-bolt can work backwards and forwards in the slot cut for it in the brackets. The axletree has a corresponding play in guides fastened to the lower edge of the brackets. The collar bolt is connected with the buffer above-mentioned, which is fixed to a transom, so that if the axletree be fixed the trail can only move by compressing the buffer. Thus, when the gun recoils, it at first only moves the trail brackets and buffer, and by means of the latter, which suffers compression, a pull is exerted on the collar-bolt and tie-bars, and thus on the axletree and wheels, which are thus put into motion.

Thus a large amount of work is done on the buffer which would otherwise act destructively on the various parts of the carriage.

The absence of a sudden shock, and the method of absorbing work by an elastic buffer, seem to render this system a peculiarly valuable one, as enabling us to fire heavy charges and shells from light guns.

The theory may be briefly stated thus :—The trail brackets are rigidly connected with the gun, and being comparatively light do not absorb a very large amount of work to put them in motion. The buffer then comes into play and absorbs work, gradually reducing the speed of recoil of gun and trail, and gradually imparting motion to the rest of the carriage.

We can easily calculate the work done on the various parts of the carriage in the case of the proposed 24-pr.

Let us assume the gun = 1350 lbs., carriage 1350 lbs., shell 24 lbs., charge 6 lbs., M.V. 1600 f.s. Then let x = velocity of recoil of gun in feet.

$$1350x = (24 + \tfrac{6}{2}) \times 1600. \quad x = 32 \text{ f.s.}$$

and energy of recoil of gun = 21,600 ft. lbs.

Suppose the first part of the carriage to weigh 550 lbs. Then

$$(1350 + 550)x' = (24 + \tfrac{6}{2}) \times 1600. \quad x' = 22{\cdot}7 \text{ ft.}$$

This is velocity of recoil of gun and first part, and its energy of recoil = 15,200 ft. lbs.

The difference between 21,600 and 15,200 = 6400 ft. lbs., and gives us the work absorbed by the material of the first part. The buffer now comes into play, and through it the rest of the carriage is moved; finally, the whole system recoils with a velocity = 16 f.s., and an energy = 10,800 ft. lbs. Thus (15,200 − 10,800) 4400 ft. lbs. are absorbed in putting the second part into motion, and much of this is absorbed by the buffer.

The principal peculiarity of the Russian carriage seems to be the great care shown in fastening the trail brackets together both by transoms and collar-bolts. Experience shows us the wisdom of this course; carriages otherwise sufficiently strong yielding by the brackets opening and bulging. This device seems to be very ingenious and well worth a trial, more especially as the large extent to which it has been adopted in the Russian service shows that it must possess more than merely theoretical advantages.

Using, then, wrought-iron only, a carriage weighing about 10 cwt. is found sufficiently strong to stand the discharge of a 27·5-lb. shell, at 1300 f.s., from a gun weighing 12 cwt. We think, then, that using steel we should be able, by means of the above-mentioned method, to fire a 24-lb. shell, 1600 f.s., from a carriage weighing 12 cwt. It will be conceded, we think, that this is not beyond the bounds of possibility.

With regard to the checking of recoil—which would be great if uncontrolled—the R.C.D. nave-breaks appear to answer very well. In cases when it is desirable to bring the gun up in a small space, two drag-shoes, one applied to each wheel, make a very powerful break. The recoil with them would probably not exceed 5 ft. on turf.

It seems advisable to abolish axletree-boxes, seats for the gunners alone being required. A couple of rounds of case can be carried in leather pockets inside the trail brackets.

The introduction of a break which, in addition to checking recoil, could be used in coming into action, going down hills, &c., so as to take the strain off the wheel horses, would be of itself an improvement which every field artilleryman will appreciate.

Ammunition.

23. We now arrive at a part of our subject which has exercised a very great influence on the effects produced by rifled guns—viz., the ammunition.

Shells; the segment.

24. We propose first to discuss the question of the projectile. As before stated, it was endeavoured on the first introduction of rifled guns to use only one nature of projectile—the segment shell; but actual service and comparative practice eventually showed that segment, neither as case, common, or shrapnel, produced as good effects as projectiles specially made for each of those purposes.

As case shot, its effect was far inferior to the ordinary nature; the segments were comparatively few, lost their velocity quickly, and ricochetted badly.

As common shell, its failure in China to set fire to junks—an object which was afterwards effected by 24-pr. S.B. Howitzers—and in New Zealand its failure to destroy stockades, from its want of a sufficient bursting charge, led to the introduction of a shell of this latter nature.

As shrapnel, it failed as a time shell; in fact, its construction and wide cone of dispersion necessitated its being burst close up to the object at which it was fired. This could only be effected by the use of a percussion fuze, and rendered an exact knowledge of the range essential. Moreover, the very curved trajectory of the guns from which it was fired rendered its effect in soft ground almost nil. During its use in the service we had not discovered a really satisfactory percussion fuze.

However, with all its defects, the segment, under favourable circumstances and at close range, up to 1500 yds. or so, was a comparatively formidable shell, and had England engaged in a European war it would have been found to be so.

25. On the Continent, where actual fighting took place, common shell reigned supreme. In 1866, and again in 1870, Prussia used nothing else. Theirs was a better shell than our common, but not nearly so good as our segment against troops in the open. Shrapnel.

The French shrapnel were almost useless, on account of the inferiority of their guns and the utter worthlessness of the fuzes. They had no very large proportion of them in their equipments. In 1870, some Saxon batteries fired a few shrapnel, and where their effect could be distinguished from that of the common shell the result is said to have been satisfactory. Since 1870 shrapnel has been introduced into nearly every equipment in Europe in some proportion. In Germany, with the new guns, about one-third is shrapnel. The introduction of this projectile naturally encountered a good deal of opposition there, but it appears that the effects obtained at practice had been so good, as officers and men have become accustomed to its use, that it will probably be carried in increased proportion. Their other projectile is a double-wall shell—an ingenious and cheap form of segment.

During the late war between Russia and Turkey the effect of shrapnel appears to have been on some occasions very marked. We believe this to have been the case whenever it was skilfully used; which, however, probably owing to the bad training of the gunners on both sides, has been but seldom. During late war.

In the Shipka pass its effect on the attacking Turks is spoken of by one correspondent as being awful. He says they were cut down by thousands by shrapnel.

Again, at the Aladja Dagh the attack on the Turkish centre appears to have owed its success chiefly to the Russian artillery, who, the "Daily News" correspondent says, used shrapnel only with excellent effect.

The Russian artillery, with the exception of that of the Guard, does not appear to be composed of sufficiently good artillerymen to use this projectile well, and a correspondent of a daily newspaper speaks of them firing for a long time at Turkish troops without ever bursting a shell nearer than 500 yds. to them. It seems odd to us why they never took the trouble to ascertain the range with a round or two of common shells and percussion fuzes. This course would at once have shown them their error.

The best weapons put into the hands of those who do not know how to use them must be nearly useless, and the Russian guns, from their very low muzzle velocity (1000 f.s.) and large calibre in proportion to weight of shell, appear to be the very worst guns one could have for shrapnel fire.

We have been induced to make the above remarks to show the value of this projectile even under adverse circumstances, and to express our belief that the want of effect of the artillery used in recent European wars has been, among other causes, due to the want of a suitable projectile.

We may take it for granted, then, that shrapnel will be the principal weapon of the Field Artillery of the Future. How then may we improve it? Improvements in shrapnel.

Of course increase of weight will enable us to insert more bullets, and in this direction we must move.

The use of a stronger material than cast-iron, such as steel, will also add much to the efficiency of shrapnel; its greatly superior strength allowing of the walls of the shell being cast much thinner and yet with sufficient strength. Greater space would thus be afforded for bullets, and a smaller proportion of the total weight be taken up by the body of the shell. It would appear possible, too, to improve the shape of the walls.

We believe, then, under these circumstances, that we could produce a 24-lb. shell containing at least

			lbs.	ozs.
110	balls, at 18 per lb.	.....	6	2
56	" 24 "	.....	2	10
Total ... 165		Weighing ...	8	12

In the 16-pr. shell, weighing over 17 lbs., we have only—

			lbs.	ozs.
72	balls, at 18 per lb.	.....	4	0
56	" 84 "	.....	0	10
Total ... 128		Weighing ...	4	10

The 84 per lb. bullets contained in the 16-pr. shell are not of much use, unless the range be short and the shell burst close up to the object, whereas those of the 24-pr. are all good.

Rules for comparative value of shells.

We have adopted, as a rough guide to the comparative effect of shrapnel, the following rules, viz.:—

(1) It is inversely proportional to the angle of descent.

The ground covered by bullet fire is nearly in this proportion: at 2000 yds., when burst 100 yds. short—so that the shell, if blind, would graze at the foot of the target—the 24-pr. covers 350 yds., and the 16-pr. only 225 yds. of ground.

(2) It is directly as the weight of lead in the shape of balls.

These rules will be allowed, we think, to be fairly correct under the varying circumstances of a campaign, when errors must often occur in the right bursting of shells. Let us apply them to the case of the guns under discussion at the range of 2000 yds. The angles of descent of 16-pr. and 24-pr. are as 8 to 5, consequently effect as 5 to 8, weight of lead as 4·66 is to 8·75, comparative effect as 23·3 is to 70; or nearly 3 to 1 in favour of the 24-pr. Comparative experiments made in Germany, after the war of 1870, between shrapnel fired from the old heavy gun and new one appear to bear out these views. The official paper on the subject says that with shrapnel the new heavy gun is three times as effective as the old at 2187 yds. range.

Large *versus* small balls.

The question also arises whether it is better to use a large number of small balls or fewer of a heavier nature.

The small balls have a slight advantage as enabling us to put rather more weight of lead into the same space than can be done with large, but within certain limits of size there is not very material difference.

A shrapnel containing small bullets must be burst closer to the object than one with larger, as the small ones lose their velocity quicker and require a higher velocity to be effective. On the other hand, the chances of hitting any individual object within the ground covered by them are increased on account of the larger number contained; but the depth of ground covered is much reduced, and as in war we cannot depend on being able to burst shells exactly where we like, it appears that fairly large balls should be used. Our 18 per lb. balls seem to answer very well, and we think should form the bulk of those used.

The following table gives the velocities of round bullets of various sizes at various distances; starting velocity = 1000 f.s.:—

Nature.	Diameter.	Range, 100 yds.	Range, 200 yds.	Range, 300 yds.
	in.	f.s.	f.s.	f.s.
18 per lb.	·65	765	620	520
24 "	·58	750	601	500
34 "	·50	739	586	487
84 "	·38	667	501	400

The velocity of 1000 f.s. is about what the proposed 24-pr. shell would have at 2000 yds. It has actually 1042 f.s.

The question is, therefore, What is the lowest velocity requisite to disable a man? Experiments carried out with a bullet 24 per lb., fired from a carbine, proved that less than 400 f.s. is sufficient to pierce a deal board $\frac{1}{2}$ in. thick; we may say, then, that this velocity is sufficient to disable, and that a 24 per lb. bullet—the smallest in the proposed 24-pr. shrapnel—would be effective 400 yds. from the burst at a range of 2000 yds.

Alloy of bullets.

It appears possible to improve our shrapnel in another way—in the material of which the bullets are composed.

Experiments have showed that it is necessary to harden the bullets by mixing some other material with the lead of which they are mainly composed. Pure lead is too soft; it loses its shape from the shock consequent on discharge, and thus exercises a great disruptive force tending to break the shell up in the gun. The action of the bursting charge would have the same effect, the result being that the flight is retarded and penetration lessened. The alloy at present used is lead and antimony. It possesses the desired hardness, but has two defects —the bullets are rendered brittle, and their weight is reduced. This is a serious matter; reduction of specific gravity of the material used means that for a desired weight the diameter must be increased. This course is very objectionable; it prevents the insertion of as many bullets into a shell body of given weight and content as would be the case were they denser and smaller. Moreover, a large diameter causes a comparatively great loss of velocity, and reduction in penetrative power, compared to a denser bullet of the same weight but smaller

diameter moving at the velocity. These considerations point out how desirable it is to discover some alloy of lead sufficiently hard and at the same time as heavy, or even heavier, than lead itself. Now, an alloy of lead and mercury is both harder and heavier than lead itself. It is generally used by elephant hunters, where these qualities are of importance in order to ensure great penetration. It is spoken of by Sir Samuel Baker in "The Nile Tributaries of Abyssinia" as being far superior to all other alloys. It, however, is expensive, and rather difficult to manage in casting, as the mercury will volatilise if raised to too high a temperature, and, being heavier than lead, sinks to the bottom if not kept stirred.

Finally, then, we may sum up the directions in which improvements in shrapnel manufacture may be expected, viz.—(1), use of steel for the bodies; (2), improved form of walls; (3), a better alloy for the bullets, if obtainable.

Common shell.

The common shell next claims our attention.

Although this projectile is not so important as shrapnel, since the chief function of field artillery seems to be that of firing at troops in the open, yet the increased importance given to field fortification demands that artillery must be prepared to make advances in its power of destroying *matériel*. In fact, against well defended works infantry is powerless; attacks, as the late war has shown, only end in useless slaughter. The Russian frequent repulses in the late war appear to have been due, in a great measure, to their sending unsupported infantry to attack works the defenders of which, their artillery, from bad handling, bad shooting, and want of power in the guns, had not sufficiently shaken. Their guns appear to have taken up a distant position, and never to have moved forward to close range to co-operate in the attack, or only did so in the case of isolated batteries. Combined action of artillery on a large scale was wanting.

The artillery must now come to the front, and by its fire render works untenable, or at least shake the moral force of the defence to such a degree as to render an attack possible. For this purpose, great accuracy (in order that as few shells as possible may be thrown away), weight and velocity of shell, and a powerful bursting charge are necessary. The proposed 24-pr. would far exceed what the 16-pr. can do. The greater energy and penetration (resulting from increased weight and velocity), and larger capacity for a bursting charge, would probably render one 24-pr., such as we speak of, worth more than two 16-prs. The common shells of the 9-pr. and 16-pr. appear to be of little use against a tolerably well constructed parapet.

Improvements in common shell; gun-cotton.

What can we do to improve our common shells? Beyond increasing weight and velocity, it appears that much might be done by using bursting charges of gun-cotton. That detonators of fulminate of mercury can safely be fired, is shown by the very few prematures among the water shell fired at Okehampton.

Experiment has shown that wet gun-cotton is perfectly safe from premature explosion. There remains the dry primer. We want a somewhat more inert substance than the service cotton, and one at the

same time capable of being detonated to a certainty by a moderate (say 15-grain) detonator. This can, we think, be produced. We must guard against prematures in the gun by careful manufacture and increased strength in the walls of our common shell. This latter step is also required to prevent that breaking up on impact so common at present, and which is a fatal defect. Prematures from defective fuzes do not appear to be so dangerous, as they generally take place outside the gun. They appear to be very rare with our present field guns, and we hope will be still more so in future. This question of prematures is one of great importance, as a burst in the bore of a gun-cotton shell would probably disable, even if it did not burst, the gun.

The effect of detonated gun-cotton is certainly equal to four times that of the same quantity of gunpowder, and we should think that the bursting of charges of 2 lbs. of cotton, which could easily be put into a strong 24-lb. shell moving with the high velocity of the proposed gun, would rapidly destroy ordinary field parapets, say from 12 to 15 ft. thick at the top. In all probability these shells would be broken up too small to be effective man-killing weapons when burst on graze in the open.

In order to estimate roughly the comparative effects of common shells when fired at earthworks or masonry, we may lay down the following rules, viz. :—

(1) Effect varies directly as the energy. The energy, of course, $= \frac{W \cdot V^2}{2g \times 2240}$ ft. tons; where W = weight of shell in lbs., and V = the striking velocity.

(2) The effect varies in a higher ratio than the bursting charge; but as we cannot express exactly what this ratio is, and to be sure of not over-estimating our power, we shall say effect varies as bursting charge.

(3) If gun-cotton be employed, the effect is from three to four times that of an equal weight of gunpowder.

What, then, would be the comparative effect of the present 16-pr. common shells and those of the proposed 24-pr. at a range of 1300 yds.?

The striking energy in foot tons is 96 in case of the 16-pr., and 216 in case of 24-pr., or as 4 is to 9. The bursting charge would be about $\frac{1}{3}$ more, or as 3 is to 4. The total effect, then, supposing gunpowder used, would be as 12 is to 36, or the 24-pr. would be three times as powerful. Supposing gun-cotton to be three times as destructive as powder, we should have the new gun nine times as effective. Let us remember, too, that supposing the 24-pr. only to shoot as well as the 16-pr., the chances of hitting what we are firing at would at this range be more than 8 to 5 in favour of the former, on account of its flatter trajectory. 16-pr. and 24-pr. compared.

These considerations certainly open up the prospect of a vast and welcome increase of power, even in the immediate future; which, however, if we obtain, will be none too soon, if future artillery is to take

its place in battle. A great opportunity is afforded by the clearly demonstrated powerlessness of infantry against even the most trifling earthworks. The Russian artillery was not able to supply the deficiency, and the result was the virtual failure of their summer campaign of 1877 in Bulgaria.

Method of loading the shell.

If we arrive at safety in using gun-cotton, it would appear that to make our bursting charge a maximum we should make a modification in the construction of our common shells. The body might be cast in one piece, in the same manner as a shrapnel, and the head be a casting of iron, or better, gun-metal, of the same thickness, screwing on to the body after the insertion of the bursting charge. This latter should be made up into a solid piece, pressed into the exact shape of the interior of the shell, and to the greatest possible density. We believe that it is possible to press gun-cotton up to a specific gravity of nearly 2·0. By this means the shell would be completely filled with a solid mass of gun-cotton, a hole being left under the bouch for the reception of the primer, the detonator and primer being of course immediately under the fuze.

It is important that the cotton should be pressed to a high density, because a great weight can be contained in a small space; the power, too, of the explosive is increased, since the particles composing it are brought into closer contact, thus rendering detonation more rapid and complete.

By loading the shell in the above manner it is probable that we should be able to insert about 2 to 2½ lbs. in a 24-lb. 3·6-in. shell with walls about ·7 thick.

When it is said that the cotton is inserted in a solid piece, we do not mean that it should be manufactured so; probably the best way would be to make it up in discs, the top and bottom pieces being moulded to the exact shape of the interior of the shell. The discs should, of course, be of the largest diameter compatible with ease of insertion in the shell.

The bursting effect of such a shell, supposing it to contain 2½ lbs. of gun-cotton, would probably equal that of the present 64-pr. containing 7 lbs. of powder.

Field parapets of ordinary strength would soon yield to the fire of guns throwing such shells with the velocity we advocate.

Penetrative power of 24-pr.

The penetrative power, as measured by the energy per inch of circumference, is only slightly less than the 64-pr. The striking velocity of the 24-pr. at 1000 yds. is 1268 f.s., energy = 270 ft. tons, and energy per inch of circumference = 24 ft. tons.

The striking velocity of the 64-pr., with a 10-lb. charge and muzzle velocity of 1360 f.s., is at 1000 yds. 1070 f.s. The energy = 508 ft. tons, and energy per inch of circumference = 25·5. Thus the 64-pr. has only a slight superiority in penetrative power.

To conclude, we must rely on increased effect from common shell in future from increased weight and velocity, and the employment of gun-cotton as a burster.

Case Shot.

Case shot. Although the opportunities for the use of case will, in future, probably be few, yet it is of the utmost importance that this projectile should be the best we can possibly make, as the safety of the guns will probably depend on the effect it produces on the occasions when it is used.

How to improve. The only means available, apparently, for increasing its power are :— (1), increase of weight; (2), increase of the proportionate charge of powder, and consequent increase of muzzle velocity; (3), the employment of a denser alloy for the bullets; (4), the substitution of steel for wrought-iron in the segmental linings.

Increase of weight will, of course, in shot of similar calibre allow of an increase in the number of bullets contained. A 24-lb. case of similar construction to the present 16-pr., which contains 176 at 16½ per lb., would hold no less than 272 of the same size.

Increase in the proportionate charge of powder. This is a most important point. The want of a sufficient charge has much to do with the falling off of the effect of case fired from rifled guns compared with that of the smooth-bore.

A denser alloy would allow of each bullet being smaller (retaining them at the same weight). In the first place, this would increase the destructive effect, as each bullet would retain its velocity longer than one of the same weight but larger diameter, and even with equal velocities would be more likely to penetrate and disable on account of its smaller area. Moreover, the smaller the diameter of each bullet, the greater number could be inserted in a case or envelope of given dimensions and weight, or a fixed number could be contained in an envelope of less size; that is to say, in a shot of given weight, a larger proportion of the total would be taken up by useful bullets and less by useless envelope.

Wrought-iron is now employed as the material of which segmental linings are made. Their chief function is to render the case so rigid as not to "set up" and take the rifling, from which would result a too great lateral depression of the bullets. This appears a work which mild steel would be far better suited to; its greater hardness and higher elastic limit would probably allow of the thickness and weight of these linings being proportionately reduced. We should by this means also obtain an increase in the weight of bullets.

Fuzes.

Fuzes. The question of fuzes is one of the highest and most vital importance. In these days, without satisfactory fuzes the best artillery that could possibly be made would hardly be of more use to an army in the field than would a catapult or balista—a very incumbrance, and useless burden. Are we in a satisfactory position? The answer must be, however much we may regret it, decidedly No! As far as percussion fuzes go, we are; but all experience of practice and actual war must convince us of the terrible (though almost latent) power of the shrapnel

shell combined with the time fuze, and with the fact that no really satisfactory fuze of this latter nature has yet been devised. Repeated instances have occurred where the shrapnel's destructive effects have been shown, but want of a really good time fuze has prevented the general extension of its power. Our own do not appear to meet the requirements of the Field Artillery of the Future, and seem to have the following defects, viz. :—

Defects of present time fuzes.

(1) At long ranges, the intervals to which they can be set are much too great. The longer the range, the nearer must the shells be burst to the object in order to get the best effects. Our 9-secs. fuze can only give ½ secs. interval. This defect, however, is not inherent, as by increasing the number of powder-channels much finer adjustment may be attained.

(2) The method of lighting is imperfect. Irregularities of burning appear to result, to some extent, from variation in the condition of the quickmatch priming used. This, however, might be remedied.

(3) The graduations might be given in yards, which would be much more simple, but that this would, with this class of fuze, entail a different fuze for each gun.

The following, however, appear to be objections fatal to usefulness and impossible to overcome :—

(1) They cannot be carried fixed. This means loss of time in service and reduction of rapidity of fire—a point of most supreme importance at critical moments.

(2) If bored at the gun, as ordered, extra work is entailed on the No. 1, who has already more than enough to do. They must be so done, as their construction renders it impossible for him to see if the operation has been correctly performed by anyone else.

(3) The length of time required to prepare renders their fire slow, and unsuitable for use at varying ranges, especially when the object fired at is moving fast. The experiment recorded at pp. 70–71, Okehampton Report, shows clearly what this loss is, although the target was stationary. With time shrapnel it took 10 minutes to fire 36 rounds; percussion 5 minutes to fire the same. The time shells disabled, it is true 182 troopers, the percussion only 131 ; but, considering the time the battery was in action, the percussion produced most effect, disabling in 5 minutes 131, while the time only disabled 91. Had the time been fired as quickly as the percussion, their superiority would have been marked. The experiment of August 27th, 1875, shows the decrease of rapidity also, 74 time being fired against 101 percussion.

(4) Errors can easily be made in the boring, even when the hook borer is used.

Time and percussion recommended.

(5) As at present constructed, there is no possibility of using a percussion fuze in combination with them. That this is desirable we think there can be little doubt. In the experiment (Okehampton No. 62, 1. 9. 75), out of 36 shrapnel (time) fired, 4 fell into the column and were blind, 2 grazed 30 yds. short and were also blind, the fuze being either knocked out on graze or extinguished. The fuzes were

too long, and thus nearly 16 per cent. were ineffective. Now, in actual war we cannot expect always to know the ranges exactly, and even the best time fuzes may fail occasionally. Under these circumstances, if a percussion arrangement is added to the time fuze, we not only are likely to get some effect when otherwise we should get none, but the burst on graze would be a most valuable indication of the correctness of the range. Moreover, the value of the simplification of the service of the gun, by having only one fuze, and that carried fixed, which is time, or percussion, or both, at pleasure, cannot be over-estimated.

A prejudice seems still to exist against this combination, arising, we think, from the bad effects obtained with the segment shell of the Armstrong period when fired thus; but we must remember that segment, from its nature, required to be burst close up to the object to develop its best effects. This could best be done by a percussion fuze. The time fuze either spoiled the result by opening the shell too soon or merely acted as a plug. On the other hand, with the shrapnel, we depend for effect chiefly on our time fuze; the percussion would only come into play when, from some cause or other, the time has failed. The percussion can in no way lessen the effect produced by a good time shell, as, of course, a time shell bursting after graze is useless. The fact, then, that a combination of time and percussion failed with the segment is no argument against its use with the shrapnel.

(6) If once bored, the present fuze is useless for any longer range, and can only be replaced by going through the long operation of finding the fuze extractor and pulling it out.

German time fuze.

The German time fuze has an ingenious arrangement for causing the shell to burst on graze, if set too long; it also appears worth imitation in its means of setting. The collar is kept firmly in its place by a nut which does not move. The collar is set by a key, without unscrewing the nut. The only preparation required is to place the key on the collar and turn an arrow mark to the range (in mètres), and the fuze being carried in the shell the whole operation takes little more time than adjusting the tangent scale.

What is required of a time fuze.

What we require, then, in a time fuze, to develop the power and extend the sphere of usefulness of shrapnel, is—

(*a*) It must be capable of being carried fixed.
(*b*) It must take a very few seconds to adjust.
(*c*) It must have alternative percussion action.
(*d*) It should be graduated in yards in such a manner that on being set to a given range the shell bursts the proper distance short. For instance: range by range-finder 2000 yds., fuze set to 2000 bursts at 1900.
(*e*) Must of course burn regularly, be free from prematures, and not deteriorate in store.

Limbers.

Limbers.

The question of reducing the weight of our limbers is one intimately associated with the future of our field artillery. In no other part of the

equipment does it appear that improvements in the material employed and method of construction can do so much. While increasing, as we must do very largely, the work done both on gun and carriage, it will tax our ingenuity to the utmost not to increase the weight. But the limber does not suffer from the heavier shock of discharge, and decrease in its weight allows of a direct increase in the weight of ammunition carried. 2 cwt. taken off the limber would allow us to add 7·5 lbs. to each of 30 rounds, and yet retain the same total weight.

One cwt. of this has already been gained by reducing the weight of the wheels, as in the case of those first used with the 12-pr. experimental gun. They apparently answered well.

Steel. Moreover, the substitution of steel for iron in the various parts, also for wood in the case of the boxes, should enable nearly 20 per cent. to be taken off the weight and yet retain the same strength.

Best type of limber. The best type of limber seems to be that now very generally adopted abroad, of boxes opening to the rear with the shells carried in separate loose boxes. This arrangement would certainly facilitate the supply of ammunition in action, especially when the gun is some distance from the limber, as a whole box full of shells, containing say five, could be sent up to the gun together. Our present system of one man running off to the limber and bringing up a single round at a time would, in most cases, decrease the rate of fire to a fearful extent. It is a remnant of the practice of a past age. The powder, too, is packed in separate boxes of copper generally.

9 cwt. is what we allow for the empty limber. The Austrians have produced one of this weight.

Howitzers.

Howitzers. The experience of the late war seems to show us that it will be advisable to re-introduce howitzers into the field service. The increased attention given to field fortification leads to this result. However powerful we make the gun proper, numerous instances will arise where troops can only be dislodged, or sufficiently shaken to render an assault possible, by an accurate and powerful vertical fire, and for this purpose we must employ howitzers.

The high-angle fire of the present field guns, from its inaccuracy and the small bursting charges of the common shells, is practically useless.

In a good field work, well provided with blindages and splinter-proofs, below the level of the ground, we might almost destroy the parapets without seriously impairing the power of the defence against assault, or even without causing many casualties. If, however, the direct fire of the gun proper be combined with a searching high-angle fire of tolerably heavy shells filled with gun-cotton, against which ordinary blindages, &c., would yield little or no protection, the *morale* of the garrison will be so shaken that an assault will probably succeed.

The weapon itself. With regard to the class of weapon to be employed, it would appear possible to utilise the present 16-pr., which experience proves to be too short as a gun. Bored up to 4·1 or 4·2 ins., if the steel tube allow, and rifled with a polygroove rifling and increasing twist, it might fire

a 32-lb. shell. It would probably be necessary to use three charges—one for bombarding purposes, one for breaching by curved fire, and one for direct fire. The lowest or bombarding charge should give an angle of descent of 35° at 1200 yds. This charge is fixed on the assumption that the howitzer should not be brought nearer than 1200 yds. to a work defended by rifles.

The highest charge in general would only be used with shrapnel, and should be such as to give about 950 f.s. at 2000 yds., beyond which the howitzer should not, as a rule, fire this projectile. A muzzle velocity of 1300 f.s. is requisite, if the calibre is 4·1 ins.

This charge would only be used with common shell when firing at troops in houses, or thick woods, or to destroy abattis, stockades, &c.

Projectiles.

The projectiles would be common shell, shrapnel, and case. The common shell would, of course, be the chief weapon, and filled with gun-cotton it would be most formidable, and quite a match for the majority of field splinter-proofs or blindages. We should recommend a proportion of about $\frac{3}{20}$ of the whole equipment to be of this nature.

A very good shrapnel might be made, combining all improvements, and with the above M.V. of 1300 f.s. would have a fair trajectory up to 2000 yds., where its final velocity of 950 f.s. would make it still efficient. It might be carried in the proportion of $\frac{6}{20}$.

Case would very rarely be required, and $\frac{1}{20}$ would meet our requirements.

The gun might take into action with it about 20 rounds, or 13 common shell, 6 shrapnel, and 1 case.

If the ammunition were supplied on the limber system, we should not require any more to accompany a gun of this nature, as the great mobility of the limbers would enable them to follow anywhere and at good speed. These limbers, to replace the ordinary wagon, should not weigh more than 10 cwt. empty, and should carry 35 rounds. These might be 23 common shell and 12 shrapnel, or a total of $11\frac{1}{2}$ cwt. of ammunition. The total weight, with $\frac{1}{2}$ cwt. of stores = 22 cwt., and would be drawn by 4 horses.

Thus we should have 20 rounds with the gun and 70 in two limbers. Total, 90 rounds.

Detail of equipment.

The weight of the equipment would be made up thus :—

	cwt.
Gun	12
Carriage	12
Limber	9
Stores	1
Ammunition	$6\frac{1}{2}$
	$40\frac{1}{2}$

Each round is assumed to weigh 37 lbs.

Place assigned to howitzers.

As to the place to be assigned to these weapons, we should not think of reverting to the old plan of mixing guns and howitzers in one battery. The defects of that system are too well known to need repetition here. They should be formed into separate batteries, and naturally would belong to the corps, not the divisional artillery. They

would thus be at the immediate disposal of the corps commander, who could use them wherever their services were especially required. In addition to their special qualities as throwing heavy common shells, their shrapnel would be of a most effective character at close range.

Possibility of realising expectations.

As before stated, with regard to the gun proper, the possibility of employing weapons of this description in the Artillery of the Future, must be solved by our capability to produce carriages and limbers of sufficient strength, and yet not exceeding—or, if possible, not reaching —the weights given above. If not, it would appear well worth the money for the Government to offer a reward to private manufacturers if they succeeded in producing what we want. Surely the mechanical ingenuity of the country is equal to the demand thus made on it.

Austria has succeeded in making a limber which only weighs 9 cwt., and Russia, with her new heavy gun, fires a shell 27 lbs. weight, with a muzzle velocity of about 1300 f.s., from a 12-cwt. gun, while the carriage for this gun, though of wrought-iron only, is said to weigh little over 10 cwt.

Reasons for introduction of howitzers.

The reasons above given for the introduction of howitzers might be greatly extended in number. Numerous instances occur in war where troops are sheltered by natural cover from direct, but where they may be greatly injured by curved or high-angle fire. To use guns with reduced charges for the purpose of searching them out is a waste of power. Their shells have not the same capacity or weight that those projected from a howitzer, of equal weight, would have, and the bulk of their ammunition (shrapnel) is not suited to this class of fire. On the other hand, a shell projected with a low velocity, so as to get a large angle of descent, must depend mainly on its bursting charge for effect.

Other cases where a powerful bursting charge is essential—such as against abattis, stockades, &c.—will present themselves to the mind of the reader.

Supply of Ammunition.

Supply of ammunition.

It seems that the present method of carrying ammunition—viz., in wagons—is not wholly satisfactory, and that the weight of the carriage itself bears too large a proportion to the weights carried.

Limber system recommended.

A better method would appear to be by means of limbers. For the gun above advocated (24-pr.) we should propose the supply of ammunition by means of two four-horse limbers. They would be heavier, and have more capacity than the gun-limber, but could, on an emergency, supply its place. The weight empty might be about 11 cwt., and they might be made to carry 12 cwt. of ammunition and stores. Forty rounds at 30 lbs. each would weigh 1200 lbs., which would allow of 144 lbs. being carried in the shape of stores, to make up 12 cwt. The total weight, with two gunners mounted, would be 26 cwt., or $6\frac{1}{2}$ cwt. per horse—a not excessive weight. Such limbers could follow the battery anywhere, and at a good pace. They would be far more mobile and handy than a wagon, and if an accident was to happen to one of them the loss to the battery would be only 40 rounds in place of 72, as would be the case if a 16-pr. wagon was disabled. The damage likely

to be caused by an explosion would be less than that of a wagon, on account of the fewer rounds carried.

In fact, such a subdivision of the ammunition supply appears to be the only method we can adopt, if we desire to take into the field a 24-pr. gun with a sufficient number of rounds. A wagon to carry 72 rounds of 24-pr. ammunition would be so heavy as to be quite out of the question. There would no extra horses required, as it appears that eight are allowed for a 16-pr. wagon. We may be permitted to hope the old, cumbrous, and awkward wagon will find no place in the Artillery of the Future. The only argument in its favour is the slightly less length of the column of route, and the facility it affords for carrying the spare wheel. However, it appears quite possible to fit a limber to carry a spare wheel underneath, and the extra length of the column of route is small; even if it were greater, it would hardly balance the many advantages to be derived from the limber system.

Armament of Gunners.

A further improvement in the defensive power of artillery might be made by arming all the gunners with a revolver; or if that be considered too dangerous, with a double-barrel breech-loading pistol. The present carbines are utterly useless in the field; they are useful only for guard purposes. The only occasions when fire-arms are likely to be of use to an artilleryman, such as when surprised by cavalry, on the march or on the field of battle, would be exactly those on which the deadly power of the revolver at close range would be of infinite service. The short range of the pistol would quite prevent any tendency of the men to leave off serving the gun to take to their fire-arm. The revolver would only come into play when the guns were temporarily useless. The bore of the pistol should be large, and a round ball would appear better than a conical. With determined gunners, under cover of the guns, a comparatively large force of cavalry might be in possession of a battery for some time without doing any serious harm, and would themselves suffer severe loss. This improvement is supported by such an authority as Sir Garnet Wolseley.

Mitrailleurs.

Question of use.

In reflecting on the power of the Field Artillery of the Future, we are naturally led to consider the question as to what place mitrailleurs will take. It appears that they have been rather too much discredited, owing to the ill-success attending their employment in 1870. This result was chiefly due to two causes—viz., the inferiority of the weapon itself, and the faulty tactics which led the French to pit it at long ranges against the German field guns, the result being, in most cases, the total discomfiture of the mitrailleur. On the other hand, there is no doubt that it often occasioned most terrible slaughter among the Germans.

Improved since 1870.

Weapons of this nature have been much improved since 1870, and the Gatling of latest pattern seems, as far as we know at present, to be the best form.

Cartridge.

The attempts to utilise the infantry cartridge have not, as yet, been a success, and it does not seem, although facilitating the supply of ammunition, that it would be a good arrangement.

Increase of weight of bullet.

The calibre of the small Gatling is ·45—the same as the Martini rifle—but it would appear advisable, in order to give it a decided superiority over infantry, to increase the weight of the bullet from 480 to, say, 600 grains, and at the same time to increase the powder charge, so as to give the heavier bullet a muzzle velocity of 1450 to 1500 f.s. We believe this could be done without increasing the weight of the present small Gatling. The comparative velocities are shown below :—

Gun.	Range, 500 yds.	Range, 1000 yds.
	f.s.	f.s.
Present.....	867	682
Proposed ...	960	771

The penetration, with equal velocities, would of course be greater in the case of the heavier bullet.

We should thus obtain a decided superiority in range and flatness of trajectory over infantry, against whom this weapon would chiefly be used.

Proportion and place.

The question now arises as to what proportion and what organisation would best develop the power of the mitrailleur with the least corresponding disadvantages.

We should advocate attaching one Gatling to each battery of artillery, though in doing so we know that there exists a strong opinion against this course. Placing Gatlings in separate batteries would undoubtedly lead to their attempting to engage artillery at long ranges, when they would be pretty sure to be silenced. Moreover, the difficulty of seeing the effect of a mitrailleur renders an exact knowledge of the range essential. Combined in the same battery with artillery, the bursts of the latter's shells would indicate this to a great extent, but in Gatling batteries only this would not be the case.

Special purposes.

The special purposes of this weapon would be :—

1st. To keep down the fire of any hostile skirmishers who might creep up within range and cause annoyance and loss to the battery. The importance of this service is manifest, more especially as this appears to be the sort of attack to which guns are most liable; direct attacks over open ground against a well posted and well served artillery firing shrapnel appearing to be pretty nearly desperate.

2nd. To aid in repulsing such an attack if made. Its effect in this way would be very important. If, as we hope will be the case, bullet-proof shields are adopted for field guns, the attack of hostile

skirmishers by shooting down the gunners will be neutralised, and if it is required to take or drive off a battery, a direct attack will be necessary in great force. It would, however, be a most sanguinary business, and ought not to succeed. The Gatling would give great aid in repulsing it.

3rd. To support the fire of the battery during the decisive moments of an attack, when the latter must often move up within infantry range, and when, in general, we may suppose the enemy's artillery more or less silenced. The chief object should then be the nearest infantry, or that which apparently does the battery most harm. The mitrailleur should pour a continuous stream of balls on them, and try to keep down their fire, thus reducing the losses of the battery, which with shielded artillery would be chiefly in horses. It is most importan that at such moments the mobility of the battery should not be seriously impaired; it would on such occasions be impossible to send the horses away, and generally be difficult to place them under cover near the battery.

4th. The mitrailleur would be most useful in repelling a charge of cavalry.

Hence the following rules for its employment:— Rules for employment.

1. On the defensive, it should be kept as much as possible under cover during the preliminary artillery combat, unless the hostile batteries, from the nature of the ground or other causes, come within 1200 or 1300 yds., when it would probably be advisable to open fire on them with the Gatling. Should they be shielded, even then it would be of little use.

2. It should open fire on the enemy's infantry at about 1500 yds., the ranges being supposed to be known and the bursts of the battery's shells giving the necessary corrections; the object of fire the same as the battery. It would then act as a seventh gun.

3. On the offensive, it should be kept under cover as much as possible during the artillery combat, but should, if possible, be placed in such a position as to command the ground in front; and those serving it should be particular to obtain the ranges of all places which would afford cover to the enemy, who, if the artillery has been pushed to the front, are sure to try to cause losses to the guns. If the guns are shielded, they will try and work out on the flanks.

4. When the battery advances to close range to support the final attack, the mitrailleur should accompany it, as above mentioned. If the enemy's guns are shielded, they must be silenced or subdued by ours. Our infantry, however demoralised the enemy's may be, will not be able to advance, if the ground be at all open, if the enemy's shielded guns can sweep them away at leisure, while our infantry can inflict little damage in return. The support of artillery will be more than ever necessary.

Objects best attained by attaching a mitrailleur to each battery.

The objects above stated appear to be more likely to be attained by dispersing the mitrailleurs among the batteries, where they can be made completely subservient to the needs of the battery and are wholly under the battery commander, than by placing them in separate batteries, which would rarely be able to carry out these tactics successfully from the difficulty which would often be experienced of finding the requisite cover close to a line of guns, and from the fact that their comparatively short range would prevent their effective fire sweeping the whole front of a mass of 8 or 10 batteries.

NOTES ON THE ORGANISATION AND EMPLOYMENT OF SIEGE ARTILLERY.

BY

CAPT. R. WALKEY, R.A.

INSTRUCTOR OF ARTILLERY, R.M.A.

(*Continued from p. 446.*)

CHAPTER II.

The Personnel of a Siege Train: Number of Artillerymen required.—Establishment for British Unit, and its Efficiency.—Duties of Artillery affected by Position of various Depôts.—Expediency of forming Siege Transport Train.—Lessons from War of 1870-1. *Arming the Batteries:* Meaning of the Term.—Armament decided by Superior Authorities. *First Artillery Position:* Circumstances governing the most suitable Ordnance.—Facilities of Arming.—Projectiles used.—Lessons from War of 1870-1. *Second Artillery Position:* Consideration of the most suitable Ordnance.—Greater Difficulties in Arming.—Projectiles used.—Time of Arming Batteries.—General Directions regarding the Arming.—Need of Care and Forethought.—Importance of Simultaneous Opening of Fire.—*Supply of Powder to Trenches:* Maintenance of Supply of Ammunition. *Reliefs:* Time for Relieving.—Strength of Reliefs. *Duties of Officers:* Superintending Batteries.—Commanding Guns. *Practical Instructions for Officers:* Their general Trench Duties.—Dismounting Guns.—Destroying Parapets.—Point of Aim.—Fire with Common, Shrapnel, and Star Shell. *Assaulting Parties:* Duties of Artillery accompanying Columns.—Carriage of Stores.—Advance of Artillery Party.

The Personnel of a Siege Train.

Basis for calculating number of artillery.

The strength of a siege train, as regards the proportion and nature of ordnance, must be decided separately for each fortress, and when determined becomes the basis for calculating the required number of artillerymen.

In estimating their number, an allowance must be made for three complete reliefs of the detachments serving the guns, with a proper proportion for casualties, camp duties, servants, the transport of ammunition to trench depôts, and the performance of various duties connected with magazines, stores, &c.

Establishment for a British unit, and consideration of its efficiency.

For purposes of administration in the British service, eight batteries of artillery, with establishments as below, have been allotted to a siege train unit, whether heavy or light.

Establishment.	For one battery.	For eight batteries.
Officers.		
Majors	1	8
Captains	1	8
Lieutenants	2	16
Total	4	32
N.C. Officers and Men.		
Battery Serjts.-Major	1	8
Serjeants	5	40
Corporals	5	40
Bombardiers	5	40
Gunners	120	960
Trumpeters	2	16
Total	138	1104
Grand total	142	1136

These 8 batteries have on charge 36 guns, 300 Hale's rockets, together with the various stores for camp equipment, entrenching tools, instruments, miscellaneous, magazine, and ordnance stores; also the ammunition, and the siege, firing, travelling, and transport carriages assigned to one unit.*

Allowing 10 men per piece, the 30 larger pieces of an unit would require 300 men for actual service at the guns, or a total of 900 to afford 3 reliefs.

Deducting from 1136 (the strength of eight batteries) 32 officers, 8 Battery Serjts.-Major, and 16 trumpeters, there remain 1080 men available for duty, or 180 (*i.e.*, 1080 — 900) beyond the number necessary to furnish 3 reliefs. 180 divided by 3 gives 60 men for each relief—*i.e.*, two men per piece for extra duties; in other words, the 8 batteries actually supply for the larger pieces in the unit 3 reliefs of 12 men each.

As a general rule, however, not more than two-thirds of the ordnance in an unit would be mounted, or at any rate be engaged at the same time, in which case the before-named equipment of 1080 men, furnishing 3 complete reliefs of 18 men per gun, appears sufficient; but it is an open question whether an establishment intended to furnish the unit complete for war purposes should not provide for all the larger ordnance being in action simultaneously. It will be observed that in the foregoing estimate no allowance is made for either the 7-pr. guns or 300 Hale's rockets.

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* *Vide* "Handbook for Field Service," 1878, pp. 240-245*y*.

Prussian organisation for siege train.

As a convenient organisation, it is suggested by Prussian authorities to assign to a company (200 strong) for permanent charge either 15^{cm} batteries of 6 guns, 12^{cm} batteries of 8 guns, 21^{cm} batteries of 4 guns, or two 9^{cm} batteries of 6 guns. By this arrangement each battery, or, if desirable, any subdivision of a battery—*i.e.*, one gun—is treated as the unit. It is worthy of consideration whether such an organisation may not be preferable to that adopted in our service.*

Duties of artillery affected by the position of the various depôts.

It must be borne in mind that the distances of the various depôts from the field arsenal will materially affect the labour demanded of the artillery. The duty of feeding the trench depôts from the intermediate ones, and these latter from the field arsenal, will fall mainly on them. No doubt in many cases the field artillery would be able to render assistance by their horses, but such help could not be continuously relied on, and if no tramway be laid, the labour of transporting ordnance and ammunition will be very considerable, varying with the state of the roads and weather. At best, however, bringing up powder, loading and unloading shells from carts, together with their storage, is heavy work, and it has now become increased by the greater weight of each projectile and powder charge.

The foregoing points must be duly considered and allowed for when estimating the number of men necessary to render any particular siege train thoroughly efficient.

Expediency of forming a "siege transport train."

As the circumstances affecting transport will vary with every fortress attacked, it would appear desirable to form a "siege transport train," in addition to, and distinct from the war establishment of troops to serve the ordnance. An organisation of this kind would simplify the calculation for each siege undertaken, relieve the detachments of many onerous duties, and probably prove itself more efficient by the men becoming better acquainted with their special duties.

Such a train was suggested after the Crimean campaign,† when great difficulties were encountered by us in the conveyance of stores, and has been organised by the Germans since their last war.

Experiences derived from war of 1870-1.

After the experience of 1866 the importance of fortress warfare was not fully recognised by the Germans, so that when called upon at once, in 1870, to despatch 288 pieces of ordnance to Strasbourg (the complete siege train prepared for service), and soon after to reinforce this number by 71 guns, whilst trains were very shortly needed for Toul and Metz, the strength and composition of the staff of the siege

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* In regard to this point, General E. Wray, C.B., states ("Proceedings, R.A. Inst." Vol. X.):—"It is manifest that under this plan (heavy and light siege train units of 30 guns each) any change found desirable or necessary in the armaments might at the last moment disarrange the whole train; whereas, by treating each gun as a unit, and keeping a proportion of each nature in reserve, complete in every respect, a siege train of any size and form required could, by a mere multiplication of units, be prepared in a few days, its establishment of men, horses, artificers, and stores calculated, and the weight of every load composing it accurately determined."

† Gen. Sir J. St. George, K.C.B., reporting on the siege operations before Sebastopol, gives it as his opinion that from 60 to 200 horses should be permanently attached to the siege train; and Major-General Sir Richard Dacres, K.C.B., strongly advocates the use of wagons and carts specially adapted for carrying shot and shell, with frames fitted in them that can be altered according to the size required. ("Proceedings, R.A. Institution," Vol. X. p. 159.)

train, as well as its preparation,* was found wholly inadequate. The fortress companies had to be made up from a strength of 86 to 400 (formed in two companies), and since the war *an increase* of the cadres of the fortress artillery and of *the strength of the establishment has been made;* further, the organisation of *a field railway detachment* to be attached to the train, and for *the transport service a special park of from 300 to 400 military wagons, has been decided on.*

It may be considered, therefore, that, under ordinary circumstances, 8 batteries per unit will furnish sufficient artillerymen; but that in certain cases, when transport duties are very severe, or nearly all the ordnance have to be served at one time, this establishment will have to be added to. The British allotment is, however, primarily intended for administrative purposes, and is of great practical value, inasmuch as, provided transport and men actually necessary to equip the unit be maintained efficient, such a portion can be set in motion at once, any further demands rendered necessary by special circumstances being supplemented afterwards.

Arming the Batteries.

Meaning of term.

Arming the batteries includes bringing up the ordnance, mounting and placing them in firing position, the supply of all ammunition and stores necessary for their service, and the laying of platforms.

In our service this last duty is usually performed by the Engineers.

Armament decided by the superior authorities.

The locality and form of each siege battery is decided by the superior authorities (Commanding Officers of the Artillery and Engineers), every work being constructed with a definite object—it may be to bombard, counter-batter, breach, or enfilade certain parts of the besieged fortress. In like manner, also, the most appropriate armament for each battery is determined by superior authority, in furtherance of the supreme object. The following considerations regarding the ordnance and ammunition for the first and second artillery positions must therefore be understood as only a very general discussion of the question, and the conclusions as liable to be more or less overweighed by exceptional or particular local circumstances.

First artillery position. General considerations determining the most suitable ordnance.

In the first artillery position, ordnance are needed—†

(1) For bombardment: (*a*) destruction of buildings, (*b*) destruction of *matériel*, (*c*) destruction of men;
(2) For fighting the enemy's artillery;
(3) For driving back the enemy within his works;
(4) For repelling sorties;

range, penetration, accuracy, with powerful common and shrapnel shell, being the chief requirements.

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* At the end of the war some 800 German pieces were on French soil available for siege purposes. To these were added a large number of siege guns belonging to the South German Artillery, &c.

† Major Kemmis' prize essay.

In the war of 1870 the extreme limit of range (3750 mètres) as laid down by the Germans was reached oftener than was expected, whilst in many cases it was deemed desirable to exceed that; so that for this position they have of late introduced a more powerful gun (the 15^{cm} ring gun, having an effective range of 8500 mètres at 40° elevation) with the special object of fighting the enemy's artillery with decisive results up to 4500 mètres, for enfilading fire up to 5000 mètres, and for bombarding up to 7500 mètres; whilst a short 21^{cm} gun is proposed with a mean range of 5000 mètres, to destroy hollow traverses and bomb-proofs more effectually.

The French say in their handbook, "The first batteries should be armed with the heaviest guns in the train, and with a few field guns to resist sorties."

The ordnance, therefore, placed in the first artillery position will principally be 64-prs., 8-in. and 6·3-in. howitzers, for enfilading, dismounting, bombarding, and searching the interior of the defences; with a few 40 or 25-prs. to drive the enemy from any ground he may be holding in front of the fortress, whilst probably the field artillery will arm any emplacements to resist sorties.

Circumstances facilitating the arming of batteries of first position.

The batteries in this position will in most cases be out of earshot of the enemy, widely dispersed,* embracing perhaps a semicircle or even more, and generally of the "elevated" type. The dispersion facilitates arming, by giving the different advancing columns a greater variety of roads along which to travel; whilst, as in elevated batteries the platforms rest on the natural surface of the ground, the arming can be carried on independent of the throwing up of the parapet, and thus the artillery can get to work at an earlier hour of the night.

In many cases batteries of the first position, being concealed from the enemy, are completed beforehand. If such be the case, night work will be rendered easier by the men being taken into the battery by day, shown the places for the guns, the position of the magazines, shell rooms, the entrances, and communications. Moreover, it may be allowable to bring up the ammunition by day; but as a rule, unless special difficulties connected with arming are foreseen, or the battery is very securely situated, the guns should not be placed in position until the night preceding the opening of fire.

Projectiles for batteries of first artillery position.

Double shell, common shell, and carcases are the projectiles chiefly used from this position for bombardment: common shell for dismounting and enfilading: shrapnel to temporarily silence the enemy's fire by driving off his gun detachments.

A few star shell† may be needed for illuminating purposes, and case might be provided in the event of a sortie being so successful as to reach the batteries, but, owing to the distance of these, such an emergency is very unlikely to occur. In the war of 1870–1, though so many sieges were undertaken by the Germans, case was not in any instance employed.

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* R.M. Academy Text-Book on Fortification, Part II., par. 319.

† At present, the effective range (about 1200 yds.) of the star shell is insufficient for use from this position.

On estimating the proportion of each description of projectile.

The proportion* of the above-named projectiles to be supplied to each battery can only be decided on the spot, after a careful consideration of the primary object to be attained by each piece and the characteristic properties of the various projectiles; the number of each nature must, however, be fixed beforehand, and the supply for each battery be disposed in the manner most suitable to facilitate their rapid conveyance to the trenches.

Lessons from war of 1870–1, to assist in above estimate.

To assist in estimating the proportion of the different projectiles, the following experiences derived from the war of 1870–1 are given:—

Double shell were found most useful for destroying supported masonry, hollow traverses, and bomb-proofs.

The *incendiary effect of common shells* was in many cases very uncertain, and delayed often for a long time; so that the introduction of a *special incendiary projectile* has since taken place.

Shrapnel fire was used to a limited extent only in the sieges, because the time of burning of the existing fuze would only permit the use of the projectile up to about 2250 mètres. A special report says:—"This must be considered a mistake; for in several cases, when the fight with the enemy's guns was carried on at some distance and was therefore indecisive, the shrapnel would have been very suitable for silencing the enemy's fire temporarily, by driving off the gun detachments. One case, which is a telling proof of this, occurred on the fourth day at the siege of Soissons."

Second artillery position. Greater difficulties in arming batteries of second position.

From this position will be fought out the great artillery battle between the besieged and besiegers. Ordnance will be required—†

(1) For fighting the enemy's artillery,
(2) For effecting breaches and demolitions,
(3) For keeping under infantry fire,
(4) For making lodgements;

and for various reasons greater difficulties are likely to be met with in arming the batteries; *e.g.*:—

The proximity of the enemy may enable him to hear the working parties, and the noise becoming a guide to him for direction, will, as well as the shorter range, render his fire more accurate.

The site of the batteries of the first position will enable him to estimate pretty correctly the probable position in which nearer batteries are likely to be formed. Thus there arises a further probability of the work being interrupted.

As the batteries will have to be constructed and armed in probably two short reliefs,‡ a different type of battery must usually be made—viz., "sunken." The earth to form such being taken from the front and rear of the parapet, the artillery will not be able to set to work

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* This point is discussed in Major Kemmis' prize essay. ("Proceedings, R.A. Inst.," Vol. X.)
† Major Kemmis' prize essay.
‡ R.M. Academy Text Book on Fortification, Part II., par. 437.

at mounting the ordnance until the ditch in rear is completed; thus their time for working becomes contracted.

Lastly, the operations have to be carried on in more confined spaces, giving the men less freedom of movement: the suppression of all noise is more important:* the approaches to the batteries will generally be fewer in number, and not so good.

General consideration of ordnance suited for second position.

The foregoing considerations, together with the shorter range, suggest that the lighter natures of ordnance—viz., 40-prs., 25-prs., and 6·3-in. howitzers—whose weight enables them to be moved with comparative ease, should generally be placed in batteries of the second artillery position.†

The French say, "Owing to the difficulty of getting up guns to the second position, the lighter natures—such as the 4·7-in. and *short* 5·9-in. (15^{cm})—will be used. The use of heavy guns is exceptional; for instance, in case iron defences have to be breached."

Suitability of the lighter natures.

Judging from recent changes made in the Prussian siege train, after lessons learnt from their last war, and experiments carefully carried out since, the pieces above named would appear sufficiently powerful for the duties demanded of them. For instance: the German short 15^{cm} with a double shell was very favourably reported on for indirect fire; and although their 12^{cm} gun (shell 30 lbs.) did not in the late sieges realise what was expected from it as a piece for dismounting purposes, yet it was considered very suitable in respect to mobility, and the gun has now been newly constructed, the range and accuracy considerably increased, to fit it for dismounting guns, and a double shell introduced, for greater penetration and effect against masonry.

Projectiles for batteries of second position.

The projectiles to be used in these batteries will be common, shrapnel, battering, and double shell, star, and case shot. The proportion of each must be based on similar considerations to those named in regard to ammunition for the first artillery position.

Time of arming.

As a rule the arming has to be done during the *night preceding opening fire*, and the batteries must be cleared ready for action by early dawn.

General directions regarding the arming of batteries.

In all cases the officers who have to perform and superintend the actual duties of arming should be informed previously of the exact description of ordnance and carriages, together with the nature and amount of ammunition to be placed in each battery or trench magazine; whilst drawings and the situations of the works should be shown them, that they may decide on what are the best means of approach,

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* Prince Hohenlohe says, in regard to armament of the *first artillery position*:—"If the wind is favourable, we may reckon with certainty that the enemy's outposts will hear nothing at 1000 or 1500 paces. Even if they remark anything, it is always questionable whether they correctly interpret the meaning of the noise. The enemy can only disturb the works with artillery fire, which fire has to be carried on by night, without the range having been determined by day, and directed upon points about the position of which nothing definite is known. Such a fire at 2500 or 4000 paces can neither disturb the construction of the batteries nor the armament."

† As 64-prs. and 8-in. howitzers perform any work in a considerably shorter time than these lighter natures, probably when the artillery fire is somewhat subdued, especial batteries may be constructed for such pieces, more particularly for breaching purposes, where time is of importance.

and estimate the stores, machines, &c., likely to be required to place the pieces in position.

Before opening fire it is presumed that such a supply of ammunition is at hand as to be certain that there is no chance of any cessation in fire through lack of it. The trench magazines will therefore have to be filled with a proper supply as regards *quantity* and *quality*. If reduced charges are to be used, care must be taken to have them ready weighed and made up beforehand; also the number and description of projectiles and fuzes should be decided on. This having been done, the complete armament for each battery should be, as far as possible, arranged separately, and a very careful examination made to see each lot is complete in every respect. The men should next be shown their exact work, and told their duties by night; they should be forewarned of the expedition required of them, the silence necessary in conducting their work, and any errors likely to be made should be pointed out.

The sites of the batteries being known, a careful inspection of the roads must be made by day, so that the position of any obstacles may be noted, and, if necessary, means taken to mark out the way so clearly as to prevent any mistakes being made in the darkness.

Necessity of care and forethought in preparing armament.

Opening fire simultaneously from all the batteries is of great importance, and therefore very careful forethought must be exercised to prevent any unlooked-for delay in arming. Want of due attention or preparation in respect to the matters just mentioned might hinder an important battery being ready to fire by the appointed hour. The advantage of the initiative would thus be lost, and probably with it the superiority of fire over certain of the enemy's works.

Importance of a simultaneous "opening of fire" by all batteries.

On the importance of this point Prince Hohenlohe writes as follows:—

"The termination of the night is the signal for 'opening fire.' It is absolutely necessary that the firing should commence as soon as day breaks, or else the enemy sees the unmasked and newly-constructed batteries, and commences his fire before we can. But in the engagement now impending the one who commences has a great advantage in being able to observe the first shots without difficulty, and consequently of making the necessary corrections. Any fortified work which is bombarded on two sides, and is hit before it can answer the fire, will have great difficulty in retaining sufficient composure to observe the effect of its own projectiles. Let any man realise the confusion of the artillery garrison, suddenly awakened from its morning's sleep by the enemy's fire, and then having to go and serve the guns on a rampart upon which shell and shrapnel are falling like hail.

"In these matters, as in war generally, surprise and initiative guarantee half the certainty of success.

"The order for opening fire must be so timed that we can calculate upon all the guns from the first artillery position opening fire simultaneously. When the 'opening' is once determined upon, it must be commenced on the appointed day as soon as there is light enough to see and to make corrections, although certain guns or batteries may not perchance be ready."

To the foregoing it need only be added that care in supplying and arming batteries of the second position is of even greater importance than in the case of those first constructed; for, by reason of their proximity to the enemy, the destruction of both guns and batteries would almost certainly result from any oversight, and thereby the entire siege operations might be seriously delayed.

Supply of cartridges to trench magazines.

As previously stated, for greater convenience, security, and protection against fire and damp, cartridges are issued in metal-lined cases. The trench magazines are usually large enough to contain a supply for two days' firing. When bringing up the powder especially, care should be taken that the men be as little as possible exposed to the enemy's fire. The cartridges must not be removed from the metal-lined cases, but these should be stowed in tiers in the magazines, in such a manner as to allow of the contents being readily got at. Empty powder-cases must be carried away by the relief, on marching out.

Maintenance of supply to trenches.

The supply of ammunition to the trenches is maintained by the men forming the new relief bringing with them either a prescribed daily allowance, or an amount regulated according to a report of the expenditure by a preceding relief.

Reliefs and General Duties in Batteries.

Time of relieving.

In regard to the most suitable time for relieving men in the batteries, Prince Hohenlohe says:—"Reliefs must take place while it is dark; therefore in the evening or early morning. The early morning relief has the advantage that the men get the range by day, and on the succeeding night have got the necessary information for carrying on the fire by night, and also for any extraordinary occurrences. On the other hand, it entails the disadvantage that the relief gets a disturbed night's rest before it comes on duty for 24 hours. This is especially so in winter, and it then comes so hard upon them that the men cannot hold out for so long when the cantonments are at any distance. Preference should therefore be given in most cases to relieving them in the evening. It is not desirable to relieve all the batteries at the same hour, as the enemy will soon remark the time at which the fire ceases in the evening, and will commence a heavy fire at the time when the double number of men gives him a double number of targets."

Strength of reliefs.

As a principle, no greater number of officers or men should be employed in the batteries (or be permitted to be present whilst firing is going on) than is considered actually necessary for the efficient superintending and service of the ordnance; otherwise the losses will become very heavy. Therefore, the strength of the relief in officers and men is governed by the number and nature of the ordnance to be used, together with a proper proportion to fill up any casualties that may occur. The detachments must be of full strength to work the pieces with facility; the officers sufficient to direct and overlook the fire. All extra numbers should be kept close at hand, but in places of safety—either out of fire or under bomb-proofs—and they must be

strictly prohibited exposing themselves to watch the fire, or on any other account.

Superintendence of batteries.

One officer per battery is usually enough, whilst a field officer can superintend a group of batteries whose communications are such as to allow of it.

Duties of superintending officers.

The superintending officers must clearly explain to those commanding batteries the general object to be attained, name the ordnance to mass fire on certain works, show what breaches are to be made, state the nature of fire to be used, the proper charges, and the points at which to direct the guns—in fact, see that each officer clearly understands the work to be performed by the guns under his immediate orders.

If breaching by indirect fire has to be undertaken, the necessary instructions should have been given beforehand by superior officers to enable the requisite angles of descent to be calculated* from the profiles of the works, and the proper charges made up. The correct elevations and times of flight, as thus deduced, should be recorded and given to the commanders of batteries, to guide them in opening fire.

Duties of those in command of batteries.

The above having been done some time prior to the relief marching off, commanders of the respective batteries should then make all necessary preparations in regard to fire, by ascertaining they have the proper description and amount of projectiles, powder charges of the correct weight, and ammunition complete in every respect. By this means no unnecessary delay in opening fire will ensue on the relief entering the batteries for the first time.

Practical instructions for those commanding in each battery.

Battery commanders must *keep a register of the nature and amount of ammunition expended* during their relief, and forward it to the proper authority, that the deficiency may be supplied by a succeeding relief.

They should also *note the elevation and charge* found correct for different objects, and report on the progress made towards completing any breach. These memoranda should be given to the relieving officer, for his information.

Special circumstances observed in regard to the enemy's conduct—such as his hour of relief, if at any particular times his fire is unusually heavy, whether night firing takes place at stated or irregular intervals, and such like information—should be remarked on, and communicated to one another by relieving officers.

The commander of the battery should *himself watch the effect of his fire* if he can do so without interference with his other duties; if not, a man trained to observe and judge carefully the effect of shot should be posted as a "look-out man," and correspondence maintained with him.

It is difficult to observe correctly from any station much on one side of the line of fire. For instance: "if the station be on the right hand, rounds grazing short may appear to fall to the left of the object, and *vice versâ*."† Pointing rods, planted near the gun, are a great assistance to the eye in judging of lateral deviations.

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* *Vide* Chapter VI., "Principles of Gunnery; Rifled Ordnance," by Major Sladen, R.A.

† "Drill Regulations for the Prussian Artillery," by which work some of these practical directions have been suggested.

Only certain men can lay a gun well, moreover, each man has his own personal error in laying: that the fire may be as accurate as possible, it is therefore desirable to select a N.C. officer or man to lay, and keep him at that duty, in the event of the officer not laying himself.

Before dark, full preparation should be made for night firing by planting picket rods, adjusting hanging scales, marking out lines of sight, &c. A few trial shots should be made, using these to ascertain that all is correct, or if not so, to make any alterations needed.

Generally speaking, it is best to *fire from one flank to the other,* commencing at that flank whence, by reason of any wind, the best observation of the fire may be obtained.

When *firing at objects difficult to see,* the following plan may be adopted:—Lay the gun accurately, with proper elevation and deflection, on the object, then plant two picket rods in the plane of sight to the front,* and notice where the line of sight cuts the first picket, make a mark at this point, and lay subsequent rounds on the mark. In dull heavy weather, or when the wind is blowing directly from the battery to the enemy, the object is often obscured for long by the smoke; time may be saved by the above method, which is also much easier than to lay on a distant work perhaps scarcely discernible.

Practical directions as to dismounting ordnance, destroying parapets, &c.

To dismount ordnance, endeavour to strike them directly. If they are under cover, try to destroy the cover as well as the guns. Shells bursting short will not prove effective for such purposes.

Parapets and traverses can be best destroyed by cutting them down from the top. Shells striking low down and bursting do but little damage; any, however, which pass through and burst will have a good local effect (the velocity being small) on men behind.

Practical directions as to "point of aim."

A general knowledge of the "vertical and horizontal zones of fire"† of the ordnance is needed as a guide to determine the point on which to lay. Practically speaking, the range may be considered as correctly found when the number of shots falling short of and beyond the object aimed at are equal, whilst the direction is so when as many fall to the right as to the left of this object.

Bearing in mind these points, and the direct result sought after from the fire, we are enabled to judge where to lay, and when the range and direction are correct. For instance: when bombarding an enemy's work generally, or enfilading certain of its faces, the point of aim would be *inside the crest of the parapet, a distance equal to half the horizontal spread of the gun;* so that shots under or over would still fall in the work and be effective. Again, to disable guns *en barbette* or on overbank carriages, the crest of the parapet would be the best point to lay on. Shots striking high might then hit the gun, and those low, passing through the weaker part of the parapet, destroy the carriages.

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* In many cases it may not be possible to plant pointing rods in front; they can, however, always be fixed in rear of the guns. By doing this, and using sights as proposed by Captain French, C.M.G., R.A. (*vide* Chapter I.), fire can be maintained with the usual accuracy, independent of all weather (rain, fog, &c.) and circumstances rendering the object obscure.

† *Vide* "Principles of Gunnery; Rifled Ordnance," Chapter VIII.

Practical directions as to fire with common, shrapnel, and star shell.

As a general rule, *common shell fire should be massed* on distinct portions of the object, and transferred from point to point, whilst *shrapnel fire should be distributed* over the whole extent of the target.

Common shell striking masonry and bursting on impact produce but little effect, only scarring the face of the wall. These projectiles, when fired even without fuzes directly into masonry, are found to explode on impact; for greater penetration it may therefore be well to fire at first shells filled and plugged, till the scarp becomes so broken that live shells can penetrate and burst behind.*

For *effective shrapnel fire,* a deep rather than wide target should be sought after; therefore, when using these projectiles to clear the parapets of the enemy, if possible, *enfilade fire should be employed,* or at any rate *oblique,* in preference to *frontal.*

Before firing star shell, several officers (if possible), *or men, should be posted with good glasses, each to observe* a certain part of the besieged fortress. The stars illuminate the enemy's position whilst falling and when burning on the ground *in rear of* his works; if they lodge to the front of the object they are useless.*

Assaulting Parties.

Duties of the artillery accompanying columns of assault.

Carriage of stores by artillery party.

It is usual for assaulting columns, consisting of the firing line, second line, and reserve, to be accompanied by a certain number of artillerymen, whose duties are to render unserviceable, by spiking or other means, any guns temporarily gained possession of; or, if the opportunity occurs, to turn them upon the besieged. For these purposes appropriate stores must be carried by the party. If the enemy's guns are to be fired, friction tubes, portfires, and cartridges should be taken. The natures of the ordnance belonging to the besieged will have been discovered long before, from projectiles which have lodged in the batteries; so that cartridges of right form can be made up ready for use. No doubt projectiles would be found near the guns themselves.

As a provision against casualties, the stores, portfires, tubes, &c., should not be all given in charge to one or two of the party, but distributed with the cartridges amidst a greater number. Moreover, each one of this number should carry what will enable a gun to be served, so that in case any of these gunners reach the enemy's ordnance, they will have the means of utilising them at hand.

Advance of artillery party with columns of assault.

Whilst the assault is being made, probably the best plan for the artillery party will be to advance with the second line, as it is the duty of this body to occupy the position as soon as it is carried by the firing line, and to meet any offensive action of the enemy to retake it. By thus accompanying the second line, the artillery will be to the front as soon as a footing is gained on any of the enemy's works, ready to take advantage of a favourable opportunity either to use or destroy any ordnance found on the spot.

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* *Vide* "Text Book on Gunnery," Part I. (Shoeburyness).

ANNUAL REPORT

AND

ABSTRACT OF PROCEEDINGS OF A GENERAL MEETING OF THE ROYAL ARTILLERY INSTITUTION, HELD ON MAY 26, 1878.

COLONEL FITZHUGH, ROYAL ARTILLERY, IN THE CHAIR.

1. THE Committee of the Royal Artillery Institution beg to submit the Annual Report to the General Meeting of Members.

2. There are now 1555 Members of the Institution (*vide* Table C, Appendix). During the past year 52 officers have joined the Institution, whilst the deaths and withdrawals have amounted to 50.

3. The financial condition of the Institution is very satisfactory, the general credit amounting to £2758.

4. The new edition of Lefroy's "Handbook for Field Service" has been published during the year, and 1500 copies have been sold.

5. A considerable sum has been expended upon the improvement of the Library, which now contains most works of repute bearing upon the military art, as well as the best text books of all the sciences.

6. The French and German Classes held in the Institution have been well attended. There has also been a Class for Landscape Drawing. Classes for the study of Mathematics, French, and Italian have been held at out stations, the expenses of which have been partly borne by the Institution.

7. The subject selected for the Prize Essay of the year was—

"On the Question whether any Development of the Matériel of Field Artillery is Necessitated by the General Adoption of Entrenchments on the Field of Battle; and if so, on the Direction such Development should take."

Seven Essays were submitted for competition.

Maj.-General Fisher, Colonel Hay, and Lt.-Colonel Fox Strangways were good enough to accept the duty of deciding upon their respective merits.

The majority of the Referees recommend that the Gold Medal be awarded to the author of the Essay bearing the motto

"Manibus victoria dextris,"

and the Silver Medal to that entitled

"Progress."

On opening the sealed envelopes bearing the respective mottoes "Manibus victoria dextris," and "Progress," Lieut. Goold-Adams was found to be the author of the Essay recommended for the Gold Medal, and Captain E. R. Elles of that to which the Silver Medal is awarded.

8. The thanks of the Members are due to Col. De Havilland and Major Higginson, for their careful audit of the Institution Accounts.

9. The following changes in the Committee have taken place during the year :—

Major Blackwell.....	vice	Major Kemmis.
Lieut.-Col. J. S. Stirling	"	" French.
Lieut. Eardley-Wilmot	"	Capt. Hime.
Lieut.-Col. Andrewes	"	Colonel P. J. Campbell.
Lieut. Newbigging	"	Lieut. Eardley-Wilmot.

It will be necessary for the Meeting to elect a Member of the Committee vice Capt. Clayton, who has received an appointment abroad.

The Committee wish to record their high appreciation of Capt. Clayton's services whilst a member of their body.

The Committee for the current year will stand thus :—

PATRON AND PRESIDENT :

Field Marshal H.R.H. the Duke of Cambridge, K.G.

VICE-PRESIDENTS :

The Inspector-General of Artillery.
The Director of Artillery and Stores.
The Deputy-Adjutant-General, R.A.
The Senior Artillery Officer doing duty at Woolwich.

MEMBERS :

The Assistant-Adjutant-General, R.A.
The Director of Artillery Studies.
The Assistant-Adjutant-General, Woolwich.
The Secretary, Department of Director of Artillery and Stores.
Lieut.-General W. J. Smythe, F.R.S.
" Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S.

Colonel H. T. FitzHugh.	Major F. Duncan.
" W. G. Andrewes.	" W. G. Brancker.
" T. H. Harris.	Capt. C. Jones.
Lieut.-Col. F. T. Whinyates.	" A. G. Yeatman-Biggs.
" W. N. Waller.	" S. C. Pratt.
Major E. J. Ward-Ashton.	" G. Mackinlay.
" J. E. Blackwell.	" J. S. Clarke.

Lieut. P. C. E. Newbigging.

Lt.-Col. M. Le Fer Taylor, *Secretary and Treasurer.*

I

Printing	Wage
	Paper
	Type
	Wood
	Litho
Photography	
Classes	
Taxidermy	
Lectures	
Library, and Book	
Museum	
Instruments.....	
Carpentry	Wage
	Mate
Furniture and Rep	
Subscriptions to S	
" refu	
Stationery	
Postage and Parce	
Incidental Expens	
Wages to Clerks a	
W.O. Photographs	
Gold and Silver Pr	
Power of Attorney	
Fire Insurance	R
	R
Cash in hand, 31st	

Dr.

Printing Type and	
Books and Periodi	
Carpentry and Pic	
Stationery	
Postage and Parce	
W.O. Lithographs	

G

Ex

J. DE HAVILL

T. C. HIGGINS

Woolw

APPENDIX.

A.

GENERAL ABSTRACT

OF THE

INCOME AND EXPENDITURE OF THE ROYAL ARTILLERY INSTITUTION,

From 1*st April*, 1878, *to* 31*st March*, 1879.

EXPENDITURE.

		£	s.	d.	£	s.	d.
Printing	Wages	169	16	1			
	Paper and Materials	286	5	2			
	Type and Furniture	16	8	6	530	18	2
	Wood Engraving	28	15	0			
	Lithography	29	13	5			
Photography					0	6	0
Classes					132	9	0
Taxidermy					10	0	0
Lectures					11	5	0
Library, and Books for Sale					491	13	2
Museum					46	10	6
Instruments					31	11	0
Carpentry	Wages	26	12	2			
	Materials and tools	159	14	2	186	6	4
Furniture and Repairs					56	18	0
Subscriptions to Societies		4	4	0			
" refunded		1	5	0	5	9	0
Stationery					123	10	10½
Postage and Parcels					90	2	3½
Incidental Expenses					53	3	11
Wages to Clerks and Orderlies					132	4	1
W.O. Photographs and Lithographs					7	16	7
Gold and Silver Prize Medals					13	6	0
Power of Attorney, Div. on Consols					0	5	0
Fire Insurance	R.A. Institution in £5000	12	10	0			
	R.A. Observatory in £1000	1	8	6	13	18	6
Cash in hand, 31st March, 1879	Of Secretary	5	12	2			
	Of Messrs. Cox & Co...	406	6	2	411	18	4
					£2349	11	9

INCOME.

		£	s.	d.	£	s.	d.
Cash in hand, 31st March, 1878					243	7	10½
Printing					133	17	8
Photography					1	12	0
Classes					59	11	9
Taxidermy					6	10	6
Books sold					300	19	7½
Instruments					1	13	6
Carpentry					53	7	5
Subscriptions	Entrance	50	0	0			
	1872-3	1	0	0			
	1873-4	1	6	0			
	1874-5	2	6	0			
	1875-6	11	4	0			
	1876-7	19	17	6			
	1877-8	38	2	6			
	1878-9	1173	16	0			
	1879-80	9	3	0			
	1880-1	1	5	0	1308	0	0
Stationery sold					122	18	4
Postage and Parcels					49	1	5
Incidental					0	1	6
W.O. Photographs and Lithographs					9	15	2
Dividends on £2000 Consols					58	15	0
					£2349	11	9

B.

Dr. DEBTOR AND CREDITOR ACCOUNT FOR THE YEAR ENDING 31st MARCH, 1879. Cr.

	£	s.	d.
Printing Type and Wood Engraving	13	15	11
Books and Periodicals	76	14	10
Carpentry and Picture Framing	6	6	8
Stationery	5	2	4
Postage and Parcels	1	13	2
W.O. Lithographs	2	4	5
General Credit, 31st March, 1879	2758	0	7
	£2863	17	11

		£	s.	d.	£	s.	d.
Cash in hand, 31st March, 1879					411	18	4
£2000 Consols Stock, at 95					1900	0	0
Value of Stock.	Printing Paper	36	1	1			
	Books for Sale	44	1	4			
	Stationery for Sale	18	8	1	133	10	6
	"Kane's Lists" (unbound)	15	0	0			
	Chemicals in Laboratory	20	0	0			
Owing by Members.	Printing	10	6	11			
	Photography	2	9	8			
	Taxidermy	5	0	0			
	Books and Binding	110	17	3			
	Carpentry	23	12	6	418	9	1
	Subscriptions	186	0	4			
	Stationery	31	4	9			
	Postage and Parcels	44	1	7			
	W.O. Lithographs	4	16	1			
					£2863	17	11

Examined and found correct,
J. DE HAVILLAND, Lt.-Col. R.A., and Colonel,
T. C. HIGGINSON, Major and Staff Paymr.

Woolwich, May 5, 1879.

The Annual Report having been read to the Meeting, it was proposed and carried,

"That the Annual Report, as read, be adopted."

The following changes in, and additions to, the Rules of the Institution were proposed by the Committee, and carried by the Meeting, viz.:—

(1) "That the last paragraph of Rule V. be cancelled, and that there be substituted for it the following:—'An Officer is only elected a Member of the Committee for three years, but he is eligible for re-election at the end of that period.'"

(2) "That in line 4 from the bottom, Rule V., the words 'and one medical officer' be omitted."

(3) "That in line 3 of Rule V. the words 'the Senior Officer of Artillery doing duty at Woolwich,' be substituted for 'the Commandant of the Garrison.'"

(4) "That every three years, or oftener, should occasion arise, and the funds of the Institution admit of it, the Committee be authorised to expend a sum not exceeding £100, to enable an officer—a Prize Medallist or other—to proceed abroad and report upon any military subject of interest selected by the Committee."

Proposed by Lt.-Col. Yonge:—

"That the Committee of the Institution be authorised to expend the sum necessary for printing and publishing the papers connected with the history of the regiment presented to the Institution on the 21st Jan., 1854, by Lieut.-Col. Samuel Cleeveland, R.A.

Put to the meeting and carried.

Captain Pratt was elected a member of the Committee vice Captain Clayton.

C.

Statement showing Increase and Decrease of Members of the R.A. Institution during the year ending 31st March, 1879.

Ranks.	31st March, 1878.	Increase.			Total increase.	Decrease.				Total decrease.	31st March, 1879.
		Promotion.	Retirement.	New members.		Promotion.	Retirement.	Withdrawal.	Death.		
EFFECTIVE LIST.											
Generals and Regimental Field Officers	495	37	—	1	38	—	11	18	5	34	499
Captains	355	56	—	1	57	37	5	1	6	49	363
Lieutenants	498	—	—	47	47	56	—	—	7	63	482
Paymasters	7	—	—	—	—	—	—	1	—	1	6
Quarter-Masters	5	—	—	—	—	—	—	—	—	—	5
Riding-Masters	4	—	—	—	—	—	—	—	1	1	3
Surgeons-Major	1	—	—	—	—	—	—	—	—	—	1
Veterinary Surgeons	4	—	—	—	—	—	—	—	—	—	4
RETIRED LIST.											
Generals and Regimental Field Officers	86	—	11	—	11	—	—	4	2	6	91
Captains	36	—	5	—	5	—	—	1	—	1	40
Lieutenants	11	—	—	—	—	—	—	—	—	—	11
Surgeons-Major	6	—	—	—	—	—	—	2	1	3	3
Surgeons	1	—	—	—	—	—	—	—	—	—	1
Chaplains	1	—	—	—	—	—	—	—	—	—	1
HONORARY MEMBERS.	43	—	—	3	3	—	—	—	1	1	45
Totals ...	1553	93	16	52	161	93	16	27	23	159	1555

D.

Presentations to the Library, &c.

Report of the Dominion of Canada Artillery Association for 1877–8	Lieut.-Col. T. B. Strange, R.A.
Canadian Militia, Manual of Field Artillery, 1878	
Prize Essay, Dominion Artillery Association, 1878	
Report of the Dominion of Canada Artillery Association, for 1878–9	The Council.
Adjutant-General's Report of the State of New York, 1872	Capt. G. A. French, C.M.G., R.A.
Art of War in Europe in 1854–6	

The French Steel R.M.L. (3·74″) Gun	Major J. F. Owen, R.A.
A Text Book of Naval Ordnance and Gunnery, by Commander Cooke, U.S. Navy	
On the Defence of England, by Col. Synge, R.E.	
Discipline and Drill, by Capt. S. F. Page	
Annual Reports of the Chief of Ordnance to the Secretary of War, 1874–7	
Ordnance Memo.: Ammunition, Fuzes, Primers, &c., by Brig.-Gen. S. V. Benit, U.S. Army	
Official Army Register, U.S. Army, Jan. 75	
Report on the Circumstances attending an Accident which occurred in the Detonator Factory of the Cotton Powder Company, at Uplees Marshes, near Faversham, 12th February, 1878	Major V. D. Majendie, R.A.
Report of the Circumstances attending an Explosion of Dynamite in Carn Brea Mine, Redruth, 27th September, 1878	
Report of the Circumstances attending an Explosion at Mr. Sharp's Gunpowder Factory, Chilworth, near Guildford, 10th Feb., 1879	
Report of the Circumstances attending an Explosion in a War Rocket Factory, at Whitehill, near Gravesend, 13th Sept. 78	
The Armies of Asia and Europe, by Gen. Upton, U.S. Army	Secretary of State for War.
War Office Photographs (32)	
Franco-German War. Translation. Section XI.	
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Memo. on Experiments with Frozen Dynamite	
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Report of the Circumstances attending an Explosion at a Gunpowder Factory at Elterwater, near Ambleside, 29th Nov., 78	Major A. Ford, R.A.
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Hart's Quarterly Army List for the Quarter ending Sept. 1877	R.A. Library.
Report on the Final Examination at the Staff College held in December, 1877	Director-Gen. of Military Education.
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Handbook for Watkin Field Range-Finder	Capt. H. S. S. Watkin, R.A.
History of "F" Battery, "B" Bde., R.H.A.	Capt. G. E. W. Malet, R.H.A.
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Geological and Geographical Atlas of Colorado, by F. V. Hayden	U.S. Government.
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The Artillerist's Handbook of Reference, by Capt. Will and Lieut. Dalton, R.A.	The Authors.
Map of the Battle Field of Gettysburg	Chief of Engineers, U.S. Army.
A Primer for Horse, Field, and Mountain Artillery, by Capt. T. H. Lloyd, R.A.	The Author.
An Enlarged Portrait of the late Maj.-General F. Eardley-Wilmot, R.A.	Mrs. Eardley-Wilmot.
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" Cadets List	
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" Independent "	
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Photograph of a Lepoha Female (1862)	
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Plan of Camp of the Royal British and German Artillery, at St. Michael, on the river St. Lawrence, 26th June, 1870	Capt. Terry, 60th Rifles, through Lt.-Col. Markham, R.A.
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A History of the Birds of Ceylon, by Capt. W. V. Legge, R.A. Part I.
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Der Organismus der Infusionsthiere, von Dr. Friedrich Ritter V. Stein.
The Kinematics of Machinery, by F. Reuleaux.
Text-Book on the Steam Engine, by T. M. Goodeve, M.A.
Die Feld-Artillerien, von R. Wille.

Cassell's Domestic Dictionary.
At Anchor: Voyage of H.M.S. Challenger.
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A Guide to the Study and Arrangement of English Coins, by H. W. Henfrey.
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English-Russian Grammar, by C. P. Reiff.
Our Schools and Colleges, by F. S. De Carteret-Bisson, M.A.
Further Papers on the Affairs of South Africa.
Arundel Society Plates:—

1. St. Giles and St. Jerome ..... by Hans Hemling.
2. St. Blaise and St. John the Baptist, "

E.

Presentations to Museum.

Brick from the Great Wall of China, at Changkia, Kau, or Kalgan. Lat. 40° 52′, long. 114° 53′	Sir H. W. Gordon, K.C.B.
Two Bamboo Spears, used by the Taepings against the Chinese Imperialists	Sir H. W. Gordon, K.C.B.
Royal Horse Artillery Busby (incomplete)	Maj.-Gen. J. B. Dennis, late R.A.
Bison Foot	Maj.-Gen. J. B. Dennis, late R.A.
Samber Foot.....	Maj.-Gen. J. B. Dennis, late R.A.
Two R.A. White Helmets.....	Maj.-Gen. J. B. Dennis, late R.A.
Cadet's Coatee and Three Epaulets	Maj.-Gen. J. B. Dennis, late R.A.
Skull of a Snapping Turtle	Maj.-Gen. J. B. Dennis, late R.A.
Bird's Nest (Bengal)	Maj.-Gen. J. B. Dennis, late R.A.
Cones, Small and Large, from a Palm Tree, 1856	Maj.-Gen. J. B. Dennis, late R.A.
Cape Girth	Maj.-Gen. J. B. Dennis, late R.A.
Chaco Chin Scales	Maj.-Gen. J. B. Dennis, late R.A.
Two Silver Grenades	Maj.-Gen. J. B. Dennis, late R.A.
Two Jungle Fowls	Maj.-Gen. J. B. Dennis, late R.A.
Tiger's Skull	Maj.-Gen. J. B. Dennis, late R.A.
White Tunic, as worn in Bengal and Bombay ...	Maj.-Gen. J. B. Dennis, late R.A.
White Belt	Maj.-Gen. J. B. Dennis, late R.A.
Stick of Sugar Cane.....	Maj.-Gen. J. B. Dennis, late R.A.
Gibraltar Monkey.....	Maj.-Gen. J. B. Dennis, late R.A.
Engraving, R.H. Artillery, 1846	Maj.-Gen. J. B. Dennis, late R.A.

F.

List of Papers published in the "Proceedings" during the Year.

Principles of Gunnery, Rifled Ordnance, by Major J. Sladen, R.A., Professor of Artillery, R.M. Academy.

Results of Experiments made in the Royal Carriage Department (July 1877) to ascertain the Relative Value, in Point of Traction, of the Service, or Service-modified, and the Madras Field Wheels and Axles. Communicated by Major W. Kemmis, R.A.

Historical Notices of the Royal Artillery (No. III.), by Major F. Duncan, LL.D., &c., R.A.

Rocket Shells, and Artillery of the Future, by Lieut. E. N. Henriques, R.A.

Translation from the French concerning a new form of Carriage for Field Ordnance firing Heavy Charges, with its application to proposed Field Guns for our own Service, by Lieut. Goold-Adams, R.A.

The Rôle of Horse Artillery in a Campaign, by Lieut. J. K. Trotter, R.H.A. (The R.A. Institution Prize Essay, 1878.)

The Rôle of Horse Artillery in a Campaign, by Lieut. T. S. Howie, R.A. (Silver Medal Prize Essay, 1878.)

On the Employment of Field Artillery in Connection with the other Arms (being an extract from the Austrian "Exerzir Reglement fur die Artillerie"). Translated by Major W. G. Brancker, R.A., and published by desire of the Director of Artillery.

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Russian Artillery Tactics during the late Campaign, by Lieut. A. M. Murray, R.A.

The Blockade of the Fortified Position of Plevna, and the surrender of the Turkish Army, 28th November, 1877. (Report of General Aide-de-Camp Todleben to His Imperial Highness the Commander-in-Chief of the Allied Armies). Translated from the Russian by Lieut. J. M. Grierson, R.A.

The War between Russia and Turkey in Asia Minor, 1877. Translated from "Löbell's Jahresberichte," by Lieut. J. M. Grierson, R.A.

The New Austrian R.B.L. (15^{cm}) 6-in. Siege Gun of Bronze-Steel, by Major J. F. Owen, R.A.

ON THE QUESTION WHETHER ANY DEVELOPMENT OF THE MATERIEL OF FIELD ARTILLERY IS NECESSITATED BY THE GENERAL ADOPTION OF ENTRENCHMENTS ON THE FIELD OF BATTLE; AND IF SO, ON THE DIRECTION SUCH DEVELOPMENT SHOULD TAKE.

BY

CAPT. E. R. ELLES, R.A.

(*The R.A. Institution Silver Medal Prize Essay, 1879.*)

"Progress."

THERE is a most instructive Persian anecdote to the following effect:—"There was once a great wrestler who had a most apt pupil. The pupil became stronger and more skilful daily; at last he thought he had mastered the whole art of wrestling and had become a greater adept than his master, so he challenged him to a wrestling match before the King for the post of court wrestler. To his great astonishment he was easily thrown by his master. 'How is this?' said he, 'I thought I had learned everything which you could teach me.' His master replied, 'I know 360 tricks in wrestling, and taught you 359 of them; but seeing that you, with your youth and strength, would become puffed up with pride, and imagine yourself my superior, I kept the 360th trick to myself, so as to defeat your pretensions.'" One moral of this story is that we should never consider ourselves perfect in anything, or be puffed up with an idea of our superiority over others. Now this is the moral that I would deduce from this story with reference to our field artillery; for I regret to state that we are rather apt to consider our field artillery very near perfection, and superior to that of other powers. Now, no doubt in most points we are equal, and in many superior; but even though we may have the advantage in 359 points, yet there is one point of superiority which they have in hand, and which, if it ever comes to a trial between us and any great European power, may turn the balance in their favour, and that point is *breech-loading*. Unfortunately, we cannot, like the young wrestler, plead ignorance of the trick to be brought against us; we are more in the position of one who, having learnt the trick, has either forgotten it or else failed to recognise its value.

In order to recognise fully the importance of breech-loading field

guns in the present day, it will be necessary to glance at the following points:—

1. The improvements in the infantry weapon of late years.
2. The increased use of field entrenchments for the defence necessitated by this improvement, and the enhanced value of any cover, however slight, owing to the rapid and deadly fire of infantry.
3. The effect of Nos. 1 and 2 on artillery tactics.

1. It is striking how we may notice in each succeeding war of importance a gradual but steadily progressive improvement in the infantry weapon.

The Crimean war introduced for the first time the rifle; the Austro-Prussian war of 1866 brought in the breech-loader; the Franco-Prussian war gave us the Chassepôt—superior to the old class of breech-loaders. In the late war in Turkey the Turks were partly armed with Peabody-Martini's, and their cavalry partly with Winchester repeating rifles.

In this gradual progress the leading features are increased range and rapidity of fire. Thus both the intensity of fire and the zone of danger have been enormously augmented. In Switzerland the infantry are now armed with repeating rifles, or magazine guns, as they are also called on the Continent.

In 1877 a Committee was formed in France to experiment with and report upon repeating rifles, and experiments have also been carried out in Austria and Germany. Austria has at present decided not to arm her infantry with repeating rifles, but in Germany it is now under consideration.

The question of long-range infantry fire has attracted attention for some years past, and has received still more notice since the Russo-Turkish war, especially in Austria, Germany, and Russia, it having been greatly employed by the Turks.*

2. Hand in hand with the increasing range and rapidity of fire of the infantry weapon, we find the use of field entrenchments becoming more and more common, until they have come to be recognised as an important factor of success for an army acting on the defensive.

In the Austro-Prussian campaign of 1866 field entrenchments were conspicuous by their absence. It is true that a few were thrown up by the Austrians at Sadowa;† but so little was their importance recognised that most of them were never occupied, the troops for whom they were intended not even knowing of their existence. Had the right flank been strongly entrenched, the result might have been very different. The villages, even along the front of the position, were not even properly prepared for defence.‡

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* "United Service Journal," No. 98, of 1878. Paper by Lieut. James, R.E.

† Prussian Official Account, campaign 1866.

‡ Colonel Cooke, R.E. Pamphlet on 1866.

In 1870–1 we find entrenchments more used—as on the heights of Spicheren, Gravelotte, and the numerous investments of fortified places.

In Turkey we have an instance of field entrenchments carried to a pitch never attempted before, at Plevna; but we must now expect to meet with a Plevna in every future campaign. Writers are rather apt to jump at the conclusion that future wars are to be wars of entrenchments and counter-entrenchments; but this idea must be received with caution, and the case of Plevna must be looked upon as exceptional, not only on account of its natural topographical advantages, but owing to the fact that a purely defensive attitude was probably forced on Osman Pasha, owing to the bad organisation of his army, which did not permit him to take the offensive; or surely an energetic commander, as he was, would have done so, after the blundering and unsuccessful attacks on Plevna by Schilder-Shulder on the 20th July, and by Krudener on the 30th July.

Enough has been said to show that the use of field entrenchments is gaining ground, and we now come to our main point—No. 3.

3. The greater use of entrenchments, and the greater defensive power of infantry combined, has rendered a longer and severer preparation by artillery fire necessary, with the object, not only of damaging the material defences, but also of overcoming the defender's power of resistance, both by the losses he sustains and by shaking his *morale*. This can only be effected by a concentrated fire from many guns directed on the chief points, or pivot points, of his defensive line. We consequently find that the proportion of artillery in armies is fully maintained—if anything, is slightly on the increase—as the following numbers will show :—*

Prussians.

1866.—1st Army,	3	corps,	49	batteries,	or	16	per corps.
2nd "	4	"	61	"		15	"
1870·—1st Army	3	"	45	"		15	"
2nd "	7	"	105	"		15	"
3rd "	6	"	96	"		16	"

Present Organisation.—Each *corps d'armée* has—

8 field batteries (4 to each infantry division).
6 field and 3 H.A. batteries for corps artillery and cavalry division.

French.

(Including artillery of 8 corps).

1870–1.—3 reserve cavalry divisions and reserve artillery.
130 batteries and 24 mitrailleurs.
Per corps: 16 batteries and 3 mitrailleurs.

Present Organisation.—8 field batteries (4 to each infantry division).
8 field and 3 H.A. batteries for corps artillery and cavalry division.

* The numbers are given by corps in order to compare with the present peace organisations, which are by corps, and consequently include the artillery attached to cavalry divisions.

The experience of the Prussians in 1866 stood the German artillery in good stead in 1870–1. In the former war we find a great want of unity of command over artillery masses.* There was too much independence of action, with a corresponding diversity of objects in view and want of unity of purpose; concentration of fire on important points was consequently seldom attained. In 1870–1 we find a complete contrast to this state of things; large masses of guns were concentrated under one command, with one special object in view. We may instance—

Mars-la-Tour, where, late in the day, we find 19 batteries concentrated between the Bois de Vionville and the high road.

Gravelotte, 31 batteries on St. Privat.

The guns were constantly pushed on to the front into most dangerous positions, and were often recklessly—sometimes uselessly—exposed to infantry fire. Heavy losses were not minded so long as the fire of the guns was conducive to the success of the general plan. They were, moreover, fully alive to the importance of closely supporting their infantry in the close attack, after the preliminary stage of preparatory fire; and this was often carried out with noble self-sacrifice on the part of the artillery.

The want of this close support to the infantry was on some occasions severely felt; their infantry had the greatest confidence in the sister arm, and justly. A notable instance of the want of this support, from no fault of the artillery, was at Spicheren, where the infantry could make no impression until closely supported by guns (on the north edge of the plateau)—an operation rendered most difficult, owing to the want of artillery positions at close ranges.†

In turning to the battles round Plevna, we may notice the following points, extracted from a most interesting work by Captain Thilo von Trotha, entitled "Der Kampf um Plevna." ("Tactical Studies"):—

1. The Russian batteries were usually distributed equally along the fighting line. There was no keeping in hand a portion of the artillery for use as corps artillery.

2. Fire was opened at long ranges, and almost always frontal. No endeavour was made to use oblique or enfilade fire (one instance alone is given).

3. The numerically weaker Turkish artillery soon gave up the contest, and withdrew their guns under cover, bringing them up again on the advance of the Russian infantry.

4. The frontal positions of the Russian artillery rendered it necessary to suspend their fire almost at the commencement of the infantry attack.

5. The cases in which batteries followed up the infantry attack and endeavoured to support them were exceptional. The artillery generally remained in their first positions, and during the second part

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* Colonel Home, Précis of Modern Tactics, and Prussian Official Account, 1866.

† Prussian Official Account, 1870–1.

of the attack played quite a secondary part, whilst the Turkish artillery, though much weaker, made its effects considerably felt during this period.

Energetic support of infantry is almost only to be found under Scobeloff's command.

The batteries which did advance with the infantry suffered so severely in men and horses as to become either totally or in part unserviceable.

The Russians found few opportunities of firing against uncovered troops; all their fire was against infantry behind either natural or artificial cover, and was almost entirely ineffective. Notwithstanding hours of preparation by the fire of powerful artillery masses, the infantry generally advanced to the attack of an unshattered enemy.*

The use of the Russian artillery, as will be seen from the above, is not such as to inspire confidence in that arm, and though in a great measure due to want of efficiency, still great stress must be laid on the fact that by judicious use of blinded cover a field work may be cannonaded for hours and yet be very little the worse for wear, whilst the losses may be almost nil;† and on the artillery having to cease fire, owing to the advance of their infantry, the defenders will be in a position to offer almost as desperate a resistance as if the cannonade had never taken place.

On the supposition that in the future field fortifications may play the same part in a campaign which they did in the Russo-Turkish war, Captain von Trotha draws the following conclusions:—

1st. That a considerable part of the field artillery must consist of considerably heavier calibres than have, up to the present time, been admitted for field artillery, in order to destroy the enemy's material defences.

2nd. That field artillery guns of the smaller calibres must not seek to produce an effect at the longer ranges, but rather by directly supporting the attacking infantry. That small detachments, of even two guns, must immediately accompany the infantry, whilst the remainder, by skilful manœuvring, should endeavour to concentrate their fire on important points, if possible from a flanking position.

The losses in men and horses will no doubt be great, and in some cases the loss of guns will be unavoidable.

A battery which, at a decisive point, can fire with destructive effect for five minutes, or even one minute, has been of more service to the general result than 10 batteries which have maintained a well-aimed but yet comparatively ineffective fire from judiciously selected positions in rear.

It has been necessary to give the outlines of artillery action in late wars, in order to be able to draw our conclusions as to the direction in which improvements should tend.

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* In the later actions and attacks.

† Instance the attack on Gornji Dubnik, on 24th October, 1877.

It is first necessary to find out what the requirements of field artillery are for modern tactics, before we can attempt to point out any changes which seem desirable to meet these requirements. But the difficulty is to lay down any definite rules for artillery tactics. The topographical configuration of the ground on which a battle is fought is a factor which it is impossible to eliminate, and which affects our tactics to an enormous extent.

It is all very well to lay down a system of artillery tactics for the attack and defence of ideal positions; but it will be found impracticable to carry out the system in fully half of any given number of positions taken hap-hazard, and such as would actually have to be occupied or attacked in war.

As examples of the difficulty of using artillery on any recognised system, I would bring forward the following two instances. In nothing is it so true that "circumstances alter cases" as in artillery tactics.

*Spicheren.**—The steep-sided plateau of Spicheren had been successfully climbed at several points by the Prussian infantry, but the southern heights were still held by strong forces of the French, and a numerous artillery swept the plateau with their fire. It was all the Prussians could do to maintain their position against the repeated attacks of the enemy. It became imperatively necessary to bring up cavalry and artillery on to the plateau. This apparent impossibility was at length surmounted, and two batteries brought up with incredible exertions by narrow steep paths through the wooded hill-side. These batteries opened fire close to the edge of the steep bank, and maintained this most precarious position in the front line, suffering enormous losses, until the end of the engagement.

The difficulty here for the artillery was caused entirely by the ground. The Spicheren heights command the valley in front by 100 ft.; on the other side of the valley are the Folster Hohe and Galgen Berg—the only available positions for artillery.

Gravelotte.†—The only position for artillery on the entire battle field of the 1st Army was on the ridge on which Gravelotte was situated, extending from 1000 paces south of the village to 800 paces north-east of Malmaison. Here 28 batteries—the whole artillery of the 1st Army—were brought into action. The form of the ravine in front was of such a nature that artillery beyond it could not, as a rule, open fire on the hostile position until the guns had advanced nearly to the crest, and this would have necessitated the occupation of the ground by infantry.

From the preceding brief sketch of the causes influencing modern tactics I would now make the following deductions:—

A.—That artillery, far from having decreased in importance on account of the improvements in the infantry weapon, has increased in value, owing to the wider use of entrenchments.

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* Borhstadt and Dwyer.

† Hoffbauer.

B.—That, owing to the increasing use of entrenchments,

1. The advantage of a breech-loading gun is unquestionable.
2. That every battery should have a supply of entrenching tools, sufficient for throwing up cover for the whole battery in the shortest practicable time.
3. That a considerable portion of field artillery must be of larger calibre than heretofore, for the purpose of destroying material defences.

C.—That the increased range and precision of the infantry weapon, and the introduction of long-range fire, render it necessary, if possible, to supply guns with self-contained protective power.

D.—That, owing to the opinion gaining ground that infantry will now more that ever require the close support of artillery, it would be advisable to introduce a light R.B.L. howitzer for field service, throwing heavy shells, to act as supporting guns to infantry in the attack of a position.

A.—This question has been briefly treated of above. The main feature is that longer and severer preparation by artillery fire is required before the infantry will be able to advance to the attack of an entrenched position with any hope of success. The enormous losses sustained by the Russians in their unsuccessful attacks at Plevna, on the 20th and 30th July, show the folly of attempting such attacks without systematic and prolonged preparation by artillery.

B.—In 1867 England possessed a large number of Armstrong B.L. field guns, but because the Armstrong gun was considered too complicated and delicate for field service, B.L. guns generally were condemned, and all our attention has since been devoted to R.M.L. guns. In the meantime all the powers of Europe* have armed their artillery with B.L. guns. Are we to suppose, then, that we are right in our persistency, and that every one else is wrong? Many countries have had the experience of large campaigns to guide them—as Austria and Prussia (1866); France and Germany (1870–1); Russia and Turkey (1877).

What advantage have we gained by retaining M.L. guns, and by our improvements in them?

It is an undeniable fact that our guns are not more accurate in their shooting than those of several other powers; they have also lower initial velocities than the corresponding guns of foreign powers, as the following table will show† :—

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* Except Sweden and Norway. America has also M.L. field guns.

† "Handbook for Field Service," 1878.

Nation.	Nature of gun.	Weight of com. shell.	Muzzle velocity.
		lbs.	f.s.
England ...	R.M.L. 16-pr.	16·2	1355
	" 9 " of 8 cwt.	9·06	1381
	" 9 " of 6 cwt.	9·06	1391
Austria ..	R.B.L. 16-pr.	16·1	1480
	" 10 "	9·5	1395
France.....	R.B.L. Reffye, 15-pr.	15·4	1280
	" " 11 "	10·6	1463
	" Lahitolle 17½ "	17·6	1558
	" " 13 "	13·2	1558
Germany	R.B.L. Krupp, 15-pr.	15·4	1456
	" " 11 "	11·2	1525
Russia.....	R.B.L. 24-pr.	24·0	1060
	" 13 "	12·6	1004

The Russian guns can scarcely be compared with the English, having much heavier projectiles for weight of metal; they are a different class of gun. The new guns now being introduced in Russia have much higher muzzle velocities.

In France, the Reffye guns are being superseded by those of the Lahitolle system.

We see from this table that our guns have lower velocities than those of France, Germany, and Austria, and that the Russian guns are alone inferior in this respect; these latter, however, are now being changed.

As one of the advantages of M.L. guns is supposed to be their stronger construction, it is rather surprising to find that our guns do not throw heavier shells for equal weights of metal, as will be seen at a glance from the following table:—

Nation.	Gun.	Weight of gun.	Common shell.	Shrapnel.
		cwt.	lbs.	lbs.
England	16-pr.	12·0	16·2 (nearly)	17·3 (nearly)
Austria	16 "	9·6	16·1	15·4
France	15 "	12·6	15·4	17·3
	17½ "	10·43	17·6	17·6
Germany	15 "	9·0	15·4	18
Russia.....	24 "	12·2	24	30

Judging from this table and the last, we may conclude that the English M.L. system requires rather greater weight of metal to throw a shell of equal weight, and that then the muzzle velocity obtained is less, as compared with French, German, and Austrian guns. This

result can hardly be considered satisfactory by the most ardent advocates of the M.L. system.*

It is rather difficult to perceive in what the advantage of M.L. guns lies. They are supposed to be stronger and less liable to injury; but the experiences of the Germans in 1870–1 do not show that breech-loaders are not strong enough for all practical purposes, or that they are too delicate for field service.

Another point adduced is that a more complicated fuze is necessary, from the absence of windage; but experience does not show this to be any difficulty. Besides, with the increased use of entrenchments and fortified pivots, percussion fuzes will be more used than heretofore.

We may now state the great points in favor of the breech-loader :—

1. That the gun requires less space for working, and is more easily loaded in a gun-pit, epaulment, or battery.
2. That in loading in a gun-pit or battery, not more than one man of the numbers at the gun is exposed to fire at a time; whereas with M.L. guns two men are always exposed at the same time, owing to the necessity of serving the vent.
3. That in the open, the numbers, being all behind the gun-carriage, are more protected from fire.†

B. 2. Entrenching Tools.—The number of entrenching tools now carried by a battery is inadequate. There should be sufficient to throw up shelter for the whole battery at the same time. The amount required, therefore, depends upon the number of men available to work, and the number which can conveniently work together. Let us take a gun-pit as the most usual kind of cover made for guns. Seven men can make a gun-pit of the regulation type in one hour; there is consequently no reason why we should not make six gun-pits in the same time, if we only have sufficient tools. I would therefore suggest that every battery be provided with 42 pickaxes, 42 shovels, and 6 spades. The spades would be very useful for cutting sods, for revetting the cheeks of embrasures, or interior slope of an epaulment, to enable them to be made at steeper slopes.

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* Particulars of the 13-pr. gun of 8 cwt., which has just been made at Woolwich, have come to hand since this essay was written. The following may be noted :—

Weight of gun	8 cwt.
" common shell	about 13 lbs.
Muzzle velocity	1530 f.s.

This is a much higher class of gun than those now in the service; it has almost the same muzzle velocity and weight of metal as the French Lahitolle 13-pr.

Lahitolle 13-pr. R.B.L.	Weight of gun	8·46 cwt.
	Muzzle velocity	1558 f.s.
	Weight of common shell	13·2 lbs.

But this still shows that with muzzle-loading we cannot beat the best breech-loading gun, and consequently bears out my arguments that it is useless keeping to M.L. guns, with their manifest disadvantages, when B.L. guns of equal power and weight of metal for shell can be constructed.

† It would no doubt be found, if any statistics could be obtained, that in action the numbers sponging and loading at M.L. guns are more frequently killed or wounded than the numbers working behind the carriage.

As this number of tools would add a considerable weight, if carried on the carriages, it would be as well to have a two-horse cart for them, to manœuvre with the wagons of the battery, so as to be close at hand when required.

At present, a battery would take at least double the minimum time necessary for entrenching itself, or else have to obtain extra tools from the infantry or engineers. Now, the former have generally quite enough work for their own establishment of tools, and the latter are not always close at hand.

The importance of artillery being able to entrench themselves quickly is greatest during a retreat, when forming part of a rear guard. An hour's digging may then have the effect of causing several hours' delay to the enemy; and, as a rule, much time will not be available for work on these occasions.

If, as some think, entrenchments are to play a great part in future wars, the entrenching tool will become one of the most important items of equipment. With an extended use of entrenchments, battles will be rarely decided in one day, unless the attacker weakens himself so severely on the first day as to be forced to retire; but we may expect to see the attacker proceed with greater caution, and, knowing the danger of throwing himself against an entrenched position, take more time over the preparatory stage of the attack. Should battles last more than one day, we shall expect to find batteries or other cover thrown up during the night at the important points, from which fire can be concentrated on the tactical pivots of the enemy's line of defence, advantage being taken of the darkness to push forward the guns to points which they could not reach during daylight except under great losses from long-range infantry fire, and artillery fire from guns strongly entrenched. It is more than probable that in the next great European war we shall see battles of several days' duration, in which artillery will play a great part.

The attack of an entrenched position is daily becoming more hopeless, unless steadily and systematically carried out; and leaders of armies will, if they hope to be successful, feel compelled to be more cautious and patient, unless they are prepared to suffer enormous losses, and thus uselessly sacrifice their men. Patience is not one of the least qualities necessary to make a good General.

B. 3.—As with guns of the same class an increase in calibre is accompanied by a corresponding decrease in mobility, there are two chief points to be considered in this question.

1. What proportion of the field artillery should consist of heavier calibres.
2. What is the heaviest gun that can be used without entirely destroying the mobility of the battery, and how far it is desirable to sacrifice mobility in order to obtain greater shell power.

1. The requirements of armies acting on the offensive, as in the case of invasion, and on the defensive, as in the case of repelling the invader

—and these are the commonest phases of war—appear to be about equal. The offensive army, on the one hand, will generally have to attack previously prepared positions; on the other hand, the importance of sacrificing mobility in order to obtain heavier guns is not so great with an army acting on the defensive.

The present proportion of artillery for the corps artillery of an English *corps d'armée* is three horse artillery and two 16-pr. batteries. This was fixed nine years ago, and should be now increased by one or two batteries.

I would propose four horse artillery and three heavy batteries. It seems advisable to increase the number of horse artillery batteries, in order to counteract, as far as possible, the loss of mobility entailed by substituting heavy field for medium field batteries.

2. As long range is a *sine quâ non*, it seems impracticable to use a gun of larger calibre than a 25-pr.; beyond this mobility may be said practically to cease. In India, we certainly have two heavy batteries of 40-prs., but the circumstances are exceptional, as they have elephants to draw the guns when not under fire; in any other country it would be impracticable. With a 25-pr. we might still have considerable manœuvring power; it would depend, however, much on the nature of the theatre of war whether even 25-prs. could be used with advantage.

There is no reason why 40-prs. should not accompany an army, but they would have to march with the ammunition reserves; they could not form part of the manœuvring portion of an army corps. As in the attack of a strongly entrenched position it is probable that cover will be thrown up, and guns placed in position during the night, it would be worth while considering whether it would not be advisable to have a 40-pr. battery per army corps with the ammunition reserve.

C.—The idea of silencing field artillery by damaging the *matériel* has now quite exploded, and it is generally recognised that this object must be attained by disabling the men and horses. Many cases could be cited where batteries have been forced to go out of action, and some cases where they have even been unable to retire, owing to the enormous losses sustained.

Hoffbauer, in his comments on the battle of Mars-la-Tour, says that many guns were obliged to cease firing until men could be brought up from the line of wagons. Towards the evening, the weakened batteries of the 5th Division were no longer able to move, in consequence of the difficulty of bringing up the wagons. Although batteries can often be kept out of infantry fire, still they may have to use case even in self-defence; that is, the hostile infantry may advance within 400 yds. range. At this range the fire of infantry will soon render a battery *hors de combat*. This occurred at Mars-la-Tour to the 5th Light, 6th Light, and 2nd H.A. Batteries of the 3rd Regiment; and at Gravelotte to the 3rd Heavy and 3rd Light Batteries of the 9th Regiment.*

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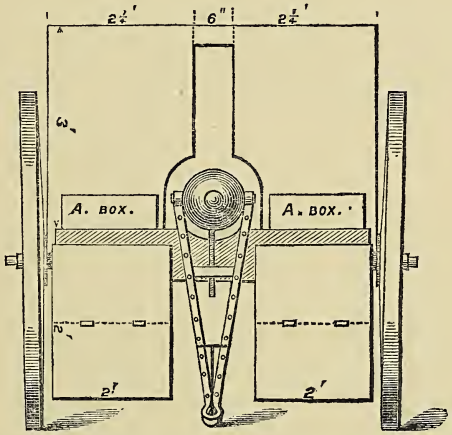
* Hoffbauer.

The very small amount of damage* done to the *matériel* in the battles of Mars-la-Tour and Gravelotte proves that the object in view should be to disable men and horses, and not *matériel;* consequently, we should endeavour to protect men and horses, as far as possible, from the fire of shrapnel and infantry—in both cases bullets.† Now, it seems by no means impracticable to afford considerable protection without much loss of mobility. Mobility is, no doubt, a most important point; but where is your mobility after a battery has been for any time exposed to fire? Having got your batteries into position, the great object is to enable them to continue their fire as long as possible. I cannot see that it is impracticable to use *steel shields* for both gun and limber, which would afford very considerable protection to the men serving the gun, and in a lesser degree to the limber horses.

Steel plates $\frac{3}{16}$ in. thick are bullet proof; that being the thickness of the "sap shields" in the service.

This gives a weight of about 7 lbs. 10 ozs. per square foot. (See diagram.)



N.B.—The upper shield could be made more rigid by a couple of stays attached to the cheeks of the trail.

The total weight for the gun would be about—

$$2 \times 3 \times 2\tfrac{1}{4} \times 7\tfrac{3}{4} \text{ lbs., above axletree.}$$
$$+2 \times 2 \times 2 \times 7\tfrac{3}{4} \text{ lbs., below "}$$
$$\text{Total weight} = (13\tfrac{1}{2} + 8) \times 7\tfrac{3}{4}$$
$$= 167 \text{ lbs.}$$

The gun must of course be a breech-loader; it is then merely improving the protection naturally afforded by the gun-carriage to the

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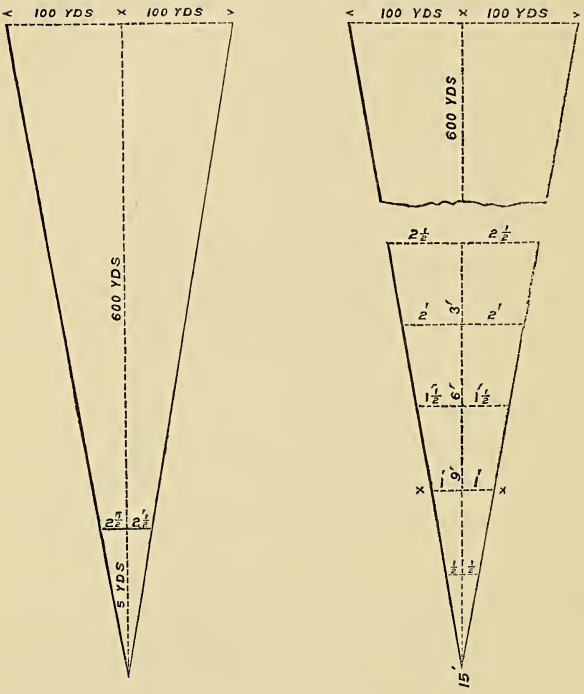
* See Hoffbauer. Returns from batteries of damages sustained.

† Shrapnel shell with time fuzes will be the projectile chiefly used by the artillery of the defenders, and common shell with percussion fuzes by the attackers of an entrenched position.

men serving the gun. The upper portions of the shields could be fixed to the front of the axletree bed; the axletree boxes opening at the breech end, and projecting through the shield towards the muzzle. The box could open with a $\frac{3}{4}$ lid. The lower portions could be fitted to the back of the axletree bed, the axle boxes being adjusted to admit of their being drawn up, or folded up, when on the move. The axletree box seats would still be available, but narrower than before. In retiring, men on these seats would be almost completely protected from fire, and if a trail seat were introduced a third number would also benefit. In action the numbers would fall to the rear instead of standing clear, still having some slight protection, except the number firing, who would have to stand as he does now.

The protection obtained by this method is best seen from the accompanying diagram.



The protecting shields have a breadth of 5 ft., including the sighting interval of 6 ins. in the centre *above* the gun. If we take a point 5 yds. (= 15 ft.) in rear of the shields, we find that at a range of 600 yds. it is covered from a line 200 yds. long, 100 yds. being on each side of the central line, or line of fire. If we suppose a man to be 2 ft. wide, we find that 3 yds. (= 9 ft.) behind the shields, standing on the central line, he will be under cover, except from fire through the central interval over 3 ft. 9 ins. from the ground. It is believed that this

method would materially decrease the casualties in action of the numbers at the gun due to shrapnel or infantry fire.

Limber.—For the limber a shield could be fitted to the back edges of the ammunition boxes, so as to fold down on the top of the boxes, and of the same width. This is rendered more feasible by the new method (which, I believe, is to be introduced) of opening ammunition boxes behind.

The size of the shield would be about $5 \times 2 = 10$ sq. ft.; weight $= 10 \times 7\frac{3}{4} = 78$ lbs. (about).

To utilise this cover, limbers in action, in exposed situations, would have to be reversed. The protection, perhaps, would not be very great, but still, every little tells; the wheelers, at all events, would be fairly covered from direct fire.

With regard to infantry fire, it may be said that batteries rarely come into action under this fire except when acting as infantry-supporting guns; as a rule, they become exposed by the advance of the infantry. Under these circumstances, the probability is that the guns will have to retire, and will prepare to do so, even now, by reversing their limbers. Consequently there will be little disadvantage, if any, in always having limbers reversed when they have to be kept under fire. It will also necessitate reversing only once instead of twice, in coming into action under fire; and it is whilst reversing that the limbers are so dangerously exposed.

During retiring, the limber gunners will be completely protected from fire, and the teams partially.

We find then that, roughly, the weight of shields required for a gun and limber will be $167 + 78 = 245$ lbs., or a little over 2 cwt.

This extra weight, though detracting from the mobility, would, I maintain, be more than compensated for by the extra protection afforded, and the prolonged *maintenance* of mobility.

The increased use of long-range fire also seems to render self-contained protection desirable. At Plevna, during the first engagements, the Russians commenced to suffer losses at distances over 2000 paces.*

Long-range fire is being rapidly reduced to a system by the chief European powers, and there seems great probability of its being employed to a considerable extent in future wars.†

For guns in support of infantry it is desirable to lessen the losses as much as possible. At Mars-la-Tour and Gravelotte guns were several times used offensively at ranges of 800 or 900 yds. against

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* "Révue Militaire," No. 432, from an article by Colonel Kouropatkin.

† In the "Journal des Sciences Militaires," for the month of March, 1879, which has been received since this essay was written, is an article entitled, "Le tir de l'Infanterie, et son Influence sur l'Emploi de l'Artillerie." This is translated from a pamphlet by Colonel Grossman, of the Austrian service. This deals with long-range infantry fire, and one conclusion drawn is as follows:—"Up to the present time, artillery have considered 800 paces as the limit to which they could advance without taking notice of infantry fire; but in the present day, this limit must be fixed at 1600 paces. At this distance artillery will be annoyed by infantry fire, and suffer loss from it."

There seems little doubt that long-range infantry fire will exercise a considerable influence on artillery tactics in the future.

infantry, and the late war in Turkey has increased the opinion that infantry must be closely supported in the future during attacks on entrenched positions. The opinion is also gaining ground—most unpalatable to artillerymen—that the loss of guns will not be held of much importance so long as the general object in view is gained. If this is the case, it would be a consolation to do as much damage as possible before the final catastrophe—that is, to maintain our fire as long as possible; and this may be greatly aided by protecting our men from infantry. This, again, can only be done by the use of steel shields. That guns under fire may often be silenced, owing to the casualties amongst the men, is fully shown in Hoffbauer's narrative.

D.—The late war in Turkey has increased the impression that infantry will require support at close ranges. This will necessitate the use of guns having the greatest mobility possible, and Captain von Trotha naturally draws the conclusion that they will have to be of the smallest calibres now in use. Since, however, long range is not so much an object, why should we not sacrifice range in order to get guns carrying a heavier shell, without decreasing the mobility? The introduction of such a gun appears attended with no special difficulty; a rifled howitzer of about 9 cwt., carrying a shell of 25 lbs., would appear to meet the case.

The advantages would be that, not only would you have a more effective projectile, especially against entrenchments, but that, owing to the greater angle of descent of the projectile, fire could be maintained much longer over the heads of advancing infantry, without endangering them—with percussion fuzes, almost up to the moment of assault.

Now, it is during the last phase of the attack that support by artillery fire is so much needed, especially in the assault of earthworks, in which blinded cover is much used. At present the defenders keep under cover until the attackers' artillery is compelled to cease firing, owing to the risk to their own infantry; they are then able to oppose the attack without exposure to artillery fire. I believe this difficulty would in a great measure be got over by the use of howitzers, as a plunging fire from heavy shells could be kept up until the last moment. This would either force the defenders to keep longer under cover, or, if they exposed themselves, inflict loss and affect their *morale*.

There are some minor points in equipment which it would be well to touch on.

Range Finding.

Every battery should have a trained range-finding party, furnished with suitable range-finders.

This is now very important, as it will be a great object to expose a battery as little as possible before it can open an *effective* fire.

The party would accompany the battery commanding officer, or other superior officer who may have to select the battery positions. As soon

as the positions have been selected, the range or ranges will be found before the battery is brought up. Fuzes might even be prepared before coming into action, so that the battery should suffer the least possible exposure during its most vulnerable time—viz., that of coming into action.

Fuzes.

The 15-secs. and 30-secs. fuzes, lately introduced, have supplied a want long felt and constantly represented.

What is now required is a special time fuze for use against infantry or cavalry, at ranges from 400 to 800 yds. This is the weak range of guns; that is to say, the value of artillery begins to decrease as that of infantry begins to increase. Shrapnel shell with percussion fuzes can certainly be used, but their effect is much less than shrapnel with time fuzes; for the bullets have an upward tendency, as the shell bursts when it is *leaving* the ground, on graze. Their effect is still less on rough or uneven ground.

To remedy this I would propose a quick-burning time fuze, the whole fuze calculated to burn out at 600 yds. It would be marked for only two other ranges—300 and 450 yds. As the fuze would be quicker burning than the present 5-secs. fuze, the boring-holes would be further apart; thus diminishing liability to inaccuracy in boring under fire. Inaccuracy would be further avoided by only having two holes which it would be possible to bore, instead of a large number.

The objections to the present fuze for short ranges are :—

1. Liability of boring-hole to fall against the metal of the bouch, and not within the shell.

2. Liability to inaccuracy of boring.

3. Liability to breaking up of the composition by hasty boring, owing to the small column of it above the boring-hole, resulting in the premature bursting of the shell.

A few fuzes such as I propose could be carried in the axletree boxes, so as to keep them entirely separate.

Pole or Shafts.

The pole *versus* shaft controversy is too well known to be revived here; but the chief disadvantage of shafts—and one rarely brought forward—is the difficulty of extricating a shaft horse when he falls. This difficulty is experienced even with an uninjured horse: it would be doubly felt with a badly injured or dead one. Now, this is a most serious inconvenience under fire, and might cause delay at a critical moment. This difficulty is obviated by the use of the pole; for with pole draught it is just as easy to extricate your off wheeler as your off leader. Shafts, too, have the disadvantage of requiring special

harness for the shaft horse. The strain on the shaft horse would certainly tell in a campaign, even if the wheelers are harnessed alternately off and near, as is generally done.

It is not at all an unusual thing to find your shaft horse thoroughly exhausted when the rest of the team show little signs of distress. This is particularly noticeable after quick work with horse artillery; and as the pace is regulated by the slowest horse, this has a serious effect on the mobility of the battery.

The superior advantages of shafts for manœuvring is a matter of little importance; for on service, manœuvring is of the very simplest description, intricate movements being out of the question.

Sights.

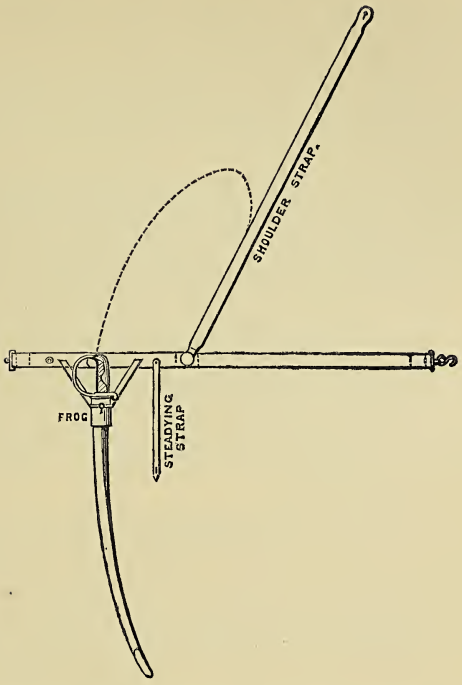
The sights with which our field guns are fitted are much too coarse. With a high initial velocity, and consequently a low trajectory, it is imperative to lay very accurately, and this cannot be done with the present sights. As it appears probable that artillery in the future will commence an action at very long ranges, an improvement in this important matter seems very desirable.

The present sight for our rifled guns is about as appropriate as a Government Enfield sight on a Rigby match rifle.

Arms of Personnel.

The heavy cavalry sword, and the mode of carrying it, are both most inappropriate for N.C. officers and gunners of horse artillery, and N.C. officers of field batteries. The sword is uselessly heavy, and is constantly getting in the way. If it is considered necessary that the men should be armed, a sword somewhat of the pattern worn by mountain battery gunners in India appears to be a suitable weapon. The sheath is of leather, and the total weight must be less than half that of the present sword. Long slings to the sword-belt are a barbarism, alike useless and inconvenient. The want of a shoulder-strap, too, is so much felt that one is nearly always worn by the men, either of leather or some other material. The sword belt *par excellence* is what is known in India as the "Sam Browne" belt. It combines comfort with utility, and would be most suitable for horse artillery gunners and N.C. officers. A rough sketch of it is here given. It could be worn without inconvenience under a horse artillery jacket.

A small strap, fixed to the belt, passes through the sword-handle, and is fastened to a small button on the belt; thus keeping the sword steady when dismounted. Having personally walked and ridden many hundred miles with this belt and sword, I can answer for its great comfort and convenience.



Carbines appear to be a rather useless article of equipment for artillery. The number might advantageously be reduced to six per battery, for camp guard duties. I know of no instance in which they have ever been used defensively by artillery.

General Remarks.

Let us endeavour, then, not to fall behind other nations in artillery matters. We should remember that in the last few years most of the great powers of Europe have had the advantage of practical experience in wars carried on against civilised foes, whilst all our campaigns since the Crimea have been against uncivilised enemies, and have been mostly of a special character, in several cases requiring special equipment—as in Abyssinia, Ashantee, and the present war at the Cape. Under these circumstances we are rather apt to lose sight of our requirements for a European war. Improvement can only be effected by keeping a close watch on what is going on amongst our neighbours, not only in time of war, but also in time of peace; for it is the experiences of war, studied and matured in time of peace, that lead to successive improvements in arms of precision. A nation strives to remedy any defects which have made themselves felt during a campaign in the succeeding period of peace.

Although we have been happily saved from such experiences, why

should we not turn them into a catspaw for ourselves, and have our chestnuts without burning our fingers ?

Our small campaigns, always successful, are the worst possible experiences for us. They even do positive harm, by making us think we have reached a high pitch of military excellence, when, as a matter of fact, we are far from it.

Most military men are not taken in by this glamour, but the public generally are. Improvement means money, and the public will not see the necessity of spending money on improvement when, according to their ideas, a high standard of excellence has been attained.

Expense should not be spared to keep our artillery up to the standard of other powers. The greatest exertions of officers and men can only produce efficiency up to a certain point: a limit is imposed upon them by the nature of the *matériel* at their disposal. If, then, the *matériel* is not kept up with the latest improvements and inventions of the day, the onus of want of efficiency will lie, not with the *personnel* of the artillery, but with the Government who refuse to sanction the expenditure necessary for the purpose.

There is no doubt that the consideration of expense alone keeps the Government from sanctioning the introduction of breech-loaders into our service. We have been armed with muzzle-loaders at a great expense, and to sanction breech-loaders now would be to admit that the money has been spent to no purpose—that our energies and money have both been wasted in a wrong direction; in fact, that we have taken our own road, contrary to the experience of other powers, but have at last reluctantly acknowledged our mistake.

The old proverb that "Practice makes perfect" might be appropriately changed, with regard to artillery matters, into "Progress makes perfect."

ON THE ROTATION REQUIRED FOR THE STABILITY OF AN ELONGATED PROJECTILE.

BY

A. G. GREENHILL, M.A.

(*Professor of Mathematics to the Advanced Class of Artillery Officers.*)

SUPPOSE an elongated projectile—for example, in the shape of a prolate spheroid—moving in infinite frictionless homogeneous liquid of density ρ under no forces.

Let O be the centre of the spheroid, OC the axis of figure, OA and OB two equatoreal radii at right angles to one another fixed in the body; and let u, v, w be the component linear velocities of the body parallel to OA, OB, and OC; and p, q, r the component angular velocities of the solid about the axes OA, OB, and OC.

If the velocity u only had existed, then the kinetic energy of the body and the surrounding liquid would be $\frac{1}{2}c_{11}u^2$; where c_{11} is a constant depending on the mass and shape of the body and the density of the liquid; c_{11} is the force which would have to act on the body for the unit of time to produce the unit of velocity parallel to OA, and is called the effective inertia of the body in the liquid in the direction OA; therefore, also, $c_{11}u$ in this case is the resultant linear momentum of the solid and liquid.

If the density of the surrounding liquid had been zero, then c_{11} would be equal to the number of units of mass M in the body; but in consequence of the velocity u of the body generating a certain state of motion in the surrounding liquid, we shall have

$$c_{11} = M\left(1 + \frac{\rho}{\sigma}\alpha\right);$$

where α is a certain constant depending on the shape of the body, σ being the density of the body.

Since the body is of revolution, it follows that if the velocity v only had existed, the kinetic energy of the system would be $\frac{1}{2}c_{11}v^2$, and the momentum $c_{11}v$.

If the velocity w only had existed, the kinetic energy of the system would be $\frac{1}{2}c_{33}w^2$, and the momentum $c_{33}w$; where

$$c_{33} = M\left(1 + \frac{\rho}{\sigma}\gamma\right),$$

and c_{33} is the effective inertia of the body in the liquid in the direction OC, γ being a constant depending on the shape of the body. In an elongated body c_{33} is obviously less than c_{11}.

For instance, if the body be a prolate spheroid of semi-axes $OC = c$, and $OA = a$, it can be proved that

$$\alpha = \frac{A}{A + C},\quad \gamma = \frac{C}{2A};$$

where

$$C = \int_0^\infty \frac{d\lambda}{(a^2+\lambda)^2\,(c^2+\lambda)^{\frac{1}{2}}} = \frac{1}{(c^2-a^2)^{\frac{3}{2}}}\log\frac{c+\sqrt{c^2-a^2}}{c-\sqrt{c^2-a^2}} - \frac{2}{c\,(c^2-a^2)},$$

$$A = \int_0^\infty \frac{d\lambda}{(a^2+\lambda)\,(c^2+\lambda)^{\frac{3}{2}}} = \frac{c}{a^2\,(c^2-a^2)} - \frac{1}{2\,(c^2-a^2)^{\frac{3}{2}}}\log\frac{c+\sqrt{c^2-a^2}}{c-\sqrt{c^2-a^2}}.$$

If the angular velocities p and q only had existed, the kinetic energy of the system would be

$$\tfrac{1}{2}c_{44}\,(p^2+q^2);$$

where c_{44} is a constant, called the effective moment of inertia of the body in the liquid about an equatoreal axis, and is equal to the couple which would have to act round an equatoreal axis of the body for the unit of time to generate the unit of angular velocity; also the components of angular momentum about the axes OA and OB would be $c_{44}p$ and $c_{44}q$.

In the prolate spheroid it can be proved that

$$c_{44} = M\tfrac{1}{5}(a^2+c^2)\left\{1 + \frac{\rho}{\sigma}\frac{C-A}{C-A+\dfrac{c^2-a^2}{c^2+a^2}(C+2A)}\right\}.$$

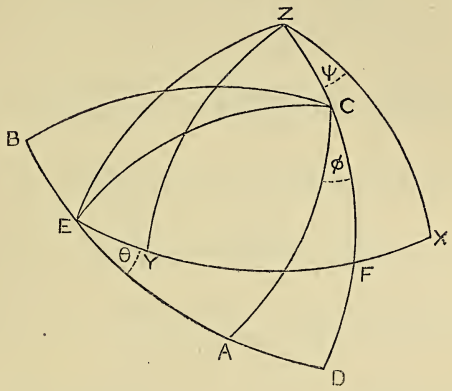
If the angular velocity r only had existed, then, since this motion of the body will not set the surrounding liquid in motion, the kinetic energy would be $\frac{1}{2}c_{66}r^2$; where c_{66} is the moment of inertia of the body about its axis of figure OC; $c_{66} = M\frac{2}{5}a^2$.

Now, if T denote the kinetic energy of the system when all the velocities u, v, w, p, q, r co-exist, T will be equal to the sum of all the separate kinetic energies due to each velocity separately, and therefore

$$T = \tfrac{1}{2}\,(c_{11}u^2 + c_{11}v^2 + c_{33}w^2 + c_{44}p^2 + c_{44}q^2 + c_{66}r^2).$$

We must now express u, v, w, p, q, r, which are estimated with respect to axes fixed in the body, in terms of co-ordinates with respect to lines fixed in space.

Let *OX, OY, OZ* be three rectangular axes drawn in fixed directions in space, meeting a sphere described with centre *O* and unit radius in



X, Y, Z. (In the figure the eye is supposed to be placed at *O*—the centre of the sphere—and to be looking at the concave side of the surface.)

Let the axes *OA, OB, OC* of the figure meet the sphere in *A, B, C.*

The axes *XYZ* may be brought into the position *ABC* by a rotation (1) through an angle ψ suppose, about the axis *OZ,* bringing them into the position *FEZ;* (2) by a rotation, through an angle θ suppose, about the axis *OE,* bringing them into the position *DEC;* and (3) by a rotation, through an angle ϕ suppose, about the axis *OC,* bringing them into the position *ABC.*

Let $\dot{x}, \dot{y}, \dot{z}$ denote the component velocities of the point *O* parallel to *OX, OY, OZ.* We must now express u, v, w, p, q, r in terms of $\dot{x}, \dot{y}, \dot{z}, \theta, \phi, \psi,$ and apply Lagrange's equations of motion,

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{x}}\right) - \frac{\delta T}{\delta x} = 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{y}}\right) - \frac{\delta T}{\delta y} = 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{z}}\right) - \frac{\delta T}{\delta z} = 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{\theta}}\right) - \frac{\delta T}{\delta \theta} = 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{\phi}}\right) - \frac{\delta T}{\delta \phi} = 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{\psi}}\right) - \frac{\delta T}{\delta \psi} = 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Since T does not contain x, y, z, therefore

$$\frac{\delta T}{\delta x} = O, \frac{\delta T}{\delta y} = O, \frac{\delta T}{\delta z} = O;$$

and therefore equations (1), (2), (3) become

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{x}}\right) = O, \frac{d}{dt}\left(\frac{\delta T}{\delta \dot{y}}\right) = O, \frac{d}{dt}\left(\frac{\delta T}{\delta \dot{z}}\right) = O.$$

The integrals of these equations may be written

$$\frac{\delta T}{\delta \dot{x}} = O, \frac{\delta T}{\delta \dot{y}} = O, \frac{\delta T}{\delta \dot{z}} = F, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

a constant, the total momentum of the system, by taking the axis of z in the direction of the resultant momentum.

Now, the components of linear momentum of the system in the directions OA, OB, OC are $c_{11}u$, $c_{11}v$, $c_{33}w$, and therefore

$$c_{11}u = F\cos AZ = -F\sin\theta\cos\phi, \quad \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$c_{11}v = F\cos BZ = F\sin\theta\sin\phi, \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$c_{33}w = F\cos CZ = F\cos\theta. \quad \ldots\ldots\ldots\ldots\ldots\ldots(10)$$

Now, the component velocities $\dot{x}, \dot{y}, \dot{z}$ are equivalent to the component velocities $\dot{x}\cos\psi + \dot{y}\sin\psi$, $-\dot{x}\sin\psi + \dot{y}\cos\psi$, $\dot{z}$ in the directions OF, OE, OZ; which, again, are equivalent to the component velocities

$(\dot{x}\cos\psi + \dot{y}\sin\psi)\cos\theta - \dot{z}\sin\theta$ in the direction OD,

$-\dot{x}\sin\psi + \dot{y}\cos\psi$ " " OE,

$(\dot{x}\cos\psi + \dot{y}\sin\psi)\sin\theta + \dot{z}\cos\theta$ " " OC;

which, again, are equivalent to the components

$\{(\dot{x}\cos\psi + \dot{y}\sin\psi)\cos\theta - \dot{z}\sin\theta\}\cos\phi + (-\dot{x}\sin\psi + \dot{y}\cos\psi)\sin\phi$

$= (\cos\theta\cos\phi\cos\psi - \sin\phi\sin\psi)\dot{x} + (\cos\theta\cos\phi\sin\psi + \sin\phi\cos\psi)\dot{y}$

$\quad - \sin\theta\cos\phi\dot{z}$

$= u$, in the direction OA;

$-\{(\dot{x}\cos\psi + \dot{y}\sin\psi)\cos\theta - \dot{z}\sin\theta\}\sin\phi + (-\dot{x}\sin\psi + \dot{y}\cos\psi)\cos\phi$

$= -(\cos\theta\sin\phi\cos\psi + \cos\phi\sin\psi)\dot{x} - (\cos\theta\sin\phi\sin\psi - \cos\phi\cos\psi)\dot{y}$

$\quad + \sin\theta\sin\phi\dot{z}$

$= v$, in the direction OB; and

$(\dot{x}\cos\psi + \dot{y}\sin\psi)\sin\theta + \dot{z}\cos\theta$

$= \sin\theta\cos\psi\dot{x} + \sin\theta\sin\psi\dot{y} + \cos\theta\dot{z}$

$= w$, in the direction OC.

Conversely, if we express $\dot{x}, \dot{y}, \dot{z}$ in terms of $u, v, w, \theta, \phi, \psi$, we shall have

$$\dot{x}\cos\psi + \dot{y}\sin\psi = \text{component velocity in the direction } OD$$

$$= (u\cos\phi - v\sin\phi)\cos\theta + w\sin\theta$$

$$= -\frac{F}{c_{11}}(\sin\theta\cos^2\phi + \sin\theta\sin^2\phi)\cos\theta + \frac{F}{c_{33}}\sin\theta\cos\theta$$

$$= F\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right)\sin\theta\cos\theta;$$

$$-\dot{x}\sin\psi + \dot{y}\cos\psi = \text{component velocity in the direction } OE$$

$$= u\sin\phi + v\cos\phi = O;$$

and therefore $$\dot{x} = F\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right)\sin\theta\cos\theta\cos\psi, \quad \text{.....(11)}$$

$$\dot{y} = F\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right)\sin\theta\cos\theta\sin\psi; \quad \text{.....(12)}$$

also $$\dot{z} = -u\sin\theta\cos\phi + v\sin\theta\sin\phi + w\cos\theta$$

$$= F\left(\frac{\cos^2\theta}{c_{33}} + \frac{\sin^2\theta}{c_{11}}\right). \quad \text{.....(13)}$$

We have therefore expressed $\dot{x}, \dot{y}, \dot{z}$—the component velocities of the point O parallel to the fixed directions OX, OY, OZ—in terms of θ, ψ, and constants, the angle ϕ not appearing; and u, v, w—the component velocities of the point O, parallel to the axes OA, OB, OC, moving in space and fixed in the body—in terms of θ, ϕ, and constants, the angle ψ not appearing.

We must now express p, q, r in terms of θ, ϕ, ψ and $\dot{\theta}, \dot{\phi}, \dot{\psi}$—their rates of increase per unit of time.

We have

$$p = \sin\phi\dot{\theta} - \sin\theta\cos\phi\dot{\psi},$$

$$q = \cos\phi\dot{\theta} + \sin\theta\sin\phi\dot{\psi},$$

$$r = \dot{\phi} + \cos\theta\dot{\psi};$$

and expressing T in terms of $\theta, \phi, \psi, \dot{\theta}, \dot{\phi}, \dot{\psi}$,

$$T = \tfrac{1}{2}F^2\left(\frac{\cos^2\theta}{c_{33}} + \frac{\sin^2\theta}{c_{11}}\right) + \tfrac{1}{2}c_{44}(\dot{\theta}^2 + \sin^2\theta\dot{\psi}^2) + \tfrac{1}{2}c_{66}(\dot{\phi} + \cos\theta\dot{\psi})^2;$$

and therefore $$\frac{\delta T}{\delta\phi} = O, \quad \frac{\delta T}{\delta\psi} = O.$$

To determine θ, ϕ, ψ as functions of t, we have by equations (4), (5) and (6), and first from equation (5),

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{\phi}}\right) = 0,$$

and therefore

$$\frac{\delta T}{\delta \dot{\phi}} = \text{constant},$$

or

$$\dot{\phi} + \cos\theta\dot{\psi} = r,$$

a constant—the angular velocity of the body about the axis OC, which therefore remains constant during the motion.

Also from (6),

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{\psi}}\right) = 0;$$

therefore

$$\frac{\delta T}{\delta \dot{\psi}} = c_{44}\sin^2\theta\dot{\psi} + c_{66}(\dot{\phi} + \cos\theta\dot{\psi})\cos\theta$$

$$= c_{44}\sin^2\theta\dot{\psi} + c_{66}r\cos\theta = G, \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

a constant—the angular momentum of the system about the axis of z.

To obtain $\frac{\delta T}{\delta\theta}$ we must differentiate the expression for T in terms of u, v, w, p, q, r; and therefore

$$\frac{\delta T}{\delta\theta} = \frac{\delta T}{\delta u}\frac{\delta u}{\delta\theta} + \frac{\delta T}{\delta v}\frac{\delta v}{\delta\theta} + \frac{\delta T}{\delta w}\frac{\delta w}{\delta\theta} + \frac{\delta T}{\delta p}\frac{\delta p}{\delta\theta} + \frac{\delta T}{\delta q}\frac{\delta q}{\delta\theta} + \frac{\delta T}{\delta r}\frac{\delta r}{\delta\theta}.$$

But

$$\frac{\delta u}{\delta\theta} = -w\cos\phi, \quad \frac{\delta v}{\delta\theta} = w\sin\phi,$$

$$\frac{\delta w}{\delta\theta} = u\cos\phi - v\sin\phi;$$

and therefore

$$\frac{\delta T}{\delta\theta} = (c_{33} - c_{11})(u\cos\phi - v\sin\phi)w + c_{44}\sin\theta\cos\theta\dot{\psi}^2 - c_{66}r\sin\theta\dot{\psi}$$

$$= F^2\sin\theta\cos\theta\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) + c_{44}\sin\theta\cos\theta\dot{\psi}^2 - c_{66}r\sin\theta\dot{\psi},$$

and

$$\frac{\delta T}{\delta\dot{\theta}} = c_{44}\dot{\theta};$$

therefore equation (4) becomes

$$c_{44}\ddot{\theta} - c_{44}\sin\theta\cos\theta\dot{\psi}^2 + c_{66}r\sin\theta\dot{\psi} - F^2\sin\theta\cos\theta\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) = 0; \quad \ldots.(15)$$

and since from equation (14), differentiating with respect to t,

$$c_{66}r \sin\theta\,\dot{\theta} = 2c_{44} \sin\theta \cos\theta\,\dot{\theta}\dot{\psi} + c_{44} \sin^2\theta\ddot{\psi},$$

therefore

$$c_{44}\ddot{\theta}\dot{\theta} + c_{44} \sin\theta \cos\theta\dot{\theta}\dot{\psi}^2 + c_{44} \sin^2\theta\dot{\psi}\ddot{\psi} - F^2 \sin\theta \cos\theta\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) = 0; \quad \ldots(16)$$

and integrating,

$$\tfrac{1}{2}c_{44}(\dot{\theta}^2 + \sin^2\theta\dot{\psi}^2) + \tfrac{1}{2}c_{66}r^2 + \tfrac{1}{2}F^2\left(\frac{\cos^2\theta}{c_{33}} + \frac{\sin^2\theta}{c_{11}}\right) = T, \quad \ldots\ldots(17)$$

a constant. The kinetic energy is therefore constant—a principle we might have assumed.

Eliminating $\dot{\psi}$ between equations (14) and (17), we shall obtain an equation the integral of which will give θ in terms of elliptic functions of t.

Considering, however, only the case of the steady motion of the body, when the point O describes a uniform helix whose axis is in the direction of the axis OZ, the angle θ between the axis OC of the body and OZ remaining constant; putting $\theta = \alpha$, a constant, and $\dot{\psi} = \mu$, a constant, and therefore $\psi = \mu t$, we have

$$\dot{x} = F\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) \sin\alpha \cos\alpha \cos\mu t,$$

$$\dot{y} = F\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) \sin\alpha \cos\alpha \sin\mu t,$$

$$\dot{z} = F\left(\frac{\cos^2\alpha}{c_{33}} + \frac{\sin^2\alpha}{c_{11}}\right);$$

and therefore

$$x = \frac{F}{\mu}\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) \sin\alpha \cos\alpha \sin\mu t,$$

$$y = -\frac{F}{\mu}\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) \sin\alpha \cos\alpha \cos\mu t,$$

$$z = F\left(\frac{\cos^2\alpha}{c_{33}} + \frac{\sin^2\alpha}{c_{11}}\right) t;$$

the equations of the helix described by the centre O of the body.

Equation (15) becomes, since $\ddot{\theta} = 0$,

$$c_{44} \sin\alpha \cos\alpha\,\mu^2 - c_{66}r \sin\alpha\,\mu + F^2 \sin\alpha \cos\alpha\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) = 0;$$

and dividing out by $\sin\alpha$,

$$c_{44} \cos\alpha\mu^2 - c_{66}r\mu + F^2\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right) \cos\alpha = 0.$$

In order that this quadratic equation should give real values of μ, we must have

$$r^2 > 4F^2 \cos^2 \alpha \frac{c_{44}}{c_{66}^2}\left(\frac{1}{c_{33}} - \frac{1}{c_{11}}\right)$$

$$> 4w^2 \frac{c_{33}c_{44}}{c_{66}^2}\left(1 - \frac{c_{33}}{c_{11}}\right).$$

Suppose the projectile fired from a rifled gun in which the rifling at the muzzle would make one turn in n calibres, and suppose β the angle the rifling at the muzzle makes with the axis of the bore; then

$$\tan \beta = \frac{\pi d}{nd} = \frac{\pi}{n};$$

d being the calibre; also

$$\tan \beta = \frac{\frac{1}{2}dr}{w};$$

w being the muzzle velocity, and r the angular velocity; therefore

$$n = \frac{2\pi w}{dr}.$$

Hence, if the rifling of the gun required to give the requisite spin make one turn in n calibres, the calibre being d, we must have

$$n = \frac{\pi}{d}\sqrt{\frac{c_{11}c_{66}^2}{c_{33}c_{44}(c_{11} - c_{33})}}.$$

Where, as in practice, the fraction $\frac{\rho}{\sigma}$, which is equal to the ratio of the weight of the air displaced to the weight of the projectile, is so small that the squares and higher powers may be neglected, then in the formula

$$n^2 = \frac{\pi^2 c_{11}c_{66}^2}{4a^2 c_{33}c_{44}(c_{11} - c_{33})}$$

we may put $$\frac{c_{11}}{c_{33}} = 1;$$

but $$c_{11} - c_{33} = M\frac{\rho}{\sigma}(\alpha - \gamma),$$

and $$c_{44} = Mk_1^2,\ c_{66} = Mk_3^2,$$

where k_1 and k_3 are the radii of gyration of the projectile about an equatoreal axis through the centre of gravity and about the axis of figure, and therefore we may put

$$n^2 = \frac{\pi^2 k_3^4}{4a^2 k_1^2 \frac{\rho}{\sigma}(\alpha - \gamma)}.$$

This formula shows, therefore, that n remains the same for similar projectiles made of the same material, whatever be the calibre.

Numerical Applications.

As numerical examples, consider firstly common unfilled shell, which may, for the purposes of theoretical calculation, be considered as prolate spheroids of which the length is three diameters, the cavity being formed by a similar surface of two-thirds the linear dimensions of the external surface.

Here $c = 3a$, and therefore

$$A = \frac{1}{a^3}\left\{\frac{3}{8} - \frac{1}{32}\sqrt{2}\log_\epsilon(3+\sqrt{8})\right\},$$

$$C = \frac{1}{a^3}\left\{\frac{1}{16}\sqrt{2}\log_\epsilon(3+\sqrt{8}) - \frac{1}{12}\right\}.$$

Now, $\log\sqrt{8} = 0{\cdot}4515450,$

therefore $\sqrt{8} = 2{\cdot}82843,$

$3 + \sqrt{8} = 5{\cdot}82843,$

$\log_{10}(3+\sqrt{8}) = 0{\cdot}7655493.$

But $\log_\epsilon(3+\sqrt{8}) = \mu\log_{10}(3+\sqrt{8}),$

where $\mu = 2{\cdot}30258509,$

and $\log_{10}\mu = 0{\cdot}3622185,$

$\log_{10}\log_{10}(3+\sqrt{8}) = \bar{1}{\cdot}8839736;$

therefore $\log_{10}\log_\epsilon(3+\sqrt{8}) = 0{\cdot}2461921,$

and $\log_\epsilon(3+\sqrt{8}) = 1{\cdot}76275.$

Also, $\log\sqrt{2} = 0{\cdot}1505150,$

therefore $\log_{10}\sqrt{2}\log_\epsilon(3+\sqrt{8}) = 0{\cdot}3967071,$

and $\sqrt{2}\log_\epsilon(3+\sqrt{8}) = 2{\cdot}49291,$

and $\frac{1}{16}\sqrt{2}\log_\epsilon(3+\sqrt{8}) = 0{\cdot}15581.$

Therefore $a^3A = \frac{3}{8} - {\cdot}0779$

$= {\cdot}3750$

$- {\cdot}0779$

$= {\cdot}2971;$

$a^3C = {\cdot}15581 - \frac{1}{12}$

$= {\cdot}15581$

$- {\cdot}08333$

$= {\cdot}0725.$

Therefore
$$\alpha = \frac{A}{A+C} = \frac{2971}{3696},$$
$$\gamma = \frac{C}{2A} = \frac{725}{5942},$$
$$\log \alpha = 3\cdot4729027$$
$$- 3\cdot5677320$$
$$= \bar{1}\cdot9051707,$$
$$\alpha = 0\cdot80385,$$
$$\log \gamma = 2\cdot8603380$$
$$- 3\cdot7739326$$
$$= \bar{1}\cdot0864054,$$
$$\gamma = 0\cdot12201,$$
and
$$\alpha - \gamma = 0\cdot68184.$$

Now,
$$\frac{\rho}{\sigma} = \frac{\text{weight of the displaced air}}{\text{weight of the shell}},$$

and the density of cast-iron is 7·207 times the density of water, while the density of air at 15·5° C. or 60° F., the height of the barometer being 30 ins., is $\frac{1}{816}$ of the density of water; therefore

$$\frac{\rho}{\sigma} = \frac{\frac{4}{3}\pi a^2 c \times \frac{1}{816}}{\frac{4}{3}\pi a^2 c\left(1 - \frac{2^3}{3^3}\right) \times 7\cdot207}$$
$$= \frac{27}{19 \times 7\cdot207 \times 816}$$
$$\log 27 = 1\cdot4313638$$
$$\log 19 = 1\cdot2787536$$
$$\log 7\cdot207 = 0\cdot8577545$$
$$\log 816 = 2\cdot9116902$$
$$\log \frac{\rho}{\sigma} = 1\cdot4313638$$
$$- 5\cdot0481983$$
$$= \bar{4}\cdot3831655,$$
$$\frac{\rho}{\sigma} = 0\cdot00024164,$$

and therefore $\frac{\rho}{\sigma}$ is a fraction small enough for the squares and higher powers to be neglected; and therefore

$$n^2 = \frac{\pi^2 k_3^4}{4a^2 k_1^2 \frac{\rho}{\sigma}(\alpha - \gamma)};$$

where k_1, k_3 are the equatoreal and polar radii of gyration of the shell, and putting $\frac{c_{33}}{c_{11}} = 1$, $c_{66} = Mk_3^2$, $c_{44} = Mk_1^2$, $c_{11} - c_{33} = M\frac{\rho}{\sigma}(\alpha - \gamma)$.

Now,
$$k_1^2 = \frac{\frac{4}{3}\pi a^2 c \cdot \frac{1}{5}(a^2 + c^2)\left(1 - \frac{2^5}{3^5}\right)}{\frac{4}{3}\pi a^2 c\left(1 - \frac{2^3}{3^3}\right)}$$
$$= \frac{211}{171} \times \frac{1}{5}(a^2 + c^2)$$
$$= \frac{211}{171} \times 2a^2, \text{ if } c = 3a;$$

and similarly,
$$k_3^2 = \frac{1 - \frac{2^5}{3^5}}{1 - \frac{2^3}{3^3}} \times \frac{2}{5}a^2$$
$$= \frac{211}{171} \times \frac{2}{5}a^2.$$

Therefore
$$n^2 = \frac{\pi^2 \times \left(\frac{211}{171}\right)^2 \times \frac{4}{25}}{4 \times \frac{211}{171} \times 2 \times \frac{\rho}{\sigma}(\alpha - \gamma)}$$
$$= \frac{211\pi^2}{50 \times 171 \times \frac{\rho}{\sigma}(\alpha - \gamma)}$$

$\log 211 = 2{\cdot}3242825,$
$\log \pi^2 = 0{\cdot}9943018;$
therefore $\log 211\pi^2 = 3{\cdot}3185843,$
$\log 50 = 1{\cdot}6989700,$
$\log 171 = 2{\cdot}2329961,$
$\log \frac{\rho}{\sigma} = \bar{4}{\cdot}3831655,$
$\log (\alpha - \gamma) = \bar{1}{\cdot}8336825$
$= 0{\cdot}1488141;$
therefore $\log n^2 = 3{\cdot}1697702,$
$\log n = 1{\cdot}5848851,$
$n = 38{\cdot}449.$

In the service guns n is generally made equal to 35.

Secondly, consider the case of double shell, unfilled, which must, for purposes of theoretical calculation, be considered as prolate spheroids

of which the length is four diameters, and the cavity is a similar surface of two-thirds the linear dimensions of the external surface.

Then $\frac{\rho}{\sigma}$ has the same value as before—viz., ·00024164; but since $c = 4a$, therefore

$$a^3 A = \frac{4}{15} - \frac{1}{15^{\frac{3}{2}}} \log_\epsilon (4 + \sqrt{15}),$$

$$a^3 C = \frac{2}{15^{\frac{3}{2}}} \log_\epsilon (4 + \sqrt{15}) - \frac{1}{30}.$$

Now, $\log \sqrt{15} = 0{\cdot}5880456,$

therefore $\sqrt{15} = 3{\cdot}8723,$

$4 + \sqrt{15} = 7{\cdot}8723,$

$\log_{10} (4 + \sqrt{15}) = 0{\cdot}8961403,$

$\log_{10} \log_{10} (4 + \sqrt{15}) = \bar{1}{\cdot}9523759,$

$\log_{10} \mu = 0{\cdot}3622185,$

$\log_{10} \log_\epsilon (4 + \sqrt{15}) = 0{\cdot}3145944,$

$\log 15^{\frac{3}{2}} = 1{\cdot}7641368,$

$\therefore \log_{10} \frac{1}{15^{\frac{3}{2}}} \log_\epsilon (4 + \sqrt{15}) = \bar{2}{\cdot}5504576,$

$\frac{1}{15^{\frac{3}{2}}} \log_\epsilon (4 + \sqrt{15}) = 0{\cdot}035518.$

Therefore

$$\begin{aligned} a^3 A &= \quad {\cdot}266666 \\ &\quad - {\cdot}035518 \\ &= \quad {\cdot}231148, \\ a^3 C &= \quad {\cdot}071036 \\ &\quad - {\cdot}033333 \\ &= \quad {\cdot}037703; \end{aligned}$$

$$\alpha = \frac{A}{A + C} = \frac{231148}{268851} = {\cdot}85977,$$

$$\gamma = \frac{C}{2A} = \frac{37703}{462296} = {\cdot}08156,$$

$$\alpha - \gamma = {\cdot}77821.$$

Also, as before,

$$k_1^2 = \frac{211}{171} \times \frac{1}{5} (a^2 + c^2)$$

$$= \frac{211}{171} \times \frac{17}{5} a^2, \text{ since } c = 4a;$$

and $$k_3^2 = \frac{211}{171} \times \frac{2}{5} a^2.$$

Therefore $$n^2 = \frac{\pi^2 \times \left(\frac{211}{171}\right)^2 \times \frac{4}{25}}{4 \times \frac{211}{171} \times \frac{17}{5} \times \frac{\rho}{\sigma} \times (\alpha - \gamma)}$$

$$= \frac{211\pi^2}{5 \times 171 \times 17 \times \frac{\rho}{\sigma} \times (\alpha - \gamma)},$$

$$\log 211\pi^2 = 3{\cdot}3185843,$$

$$\log 5 = 0{\cdot}6989700,$$

$$\log 171 = 2{\cdot}2329961,$$

$$\log 17 = 1{\cdot}2304489,$$

$$\log \frac{\rho}{\sigma} = \bar{4}{\cdot}3831655,$$

$$\log (\alpha - \gamma) = \frac{\bar{1}{\cdot}8910968}{0{\cdot}4366773};$$

therefore $$\log n^2 = 2{\cdot}8819070,$$

$$\log n = 1{\cdot}4409535;$$

therefore $$n = 27{\cdot}603.$$

Consequently, even for double shell, the twist in the 6·3-in. and the 8-in. howitzers—one turn in sixteen calibres—seems excessive; the spin imparted being theoretically far in excess of what is required for stability, the only effect of the excess of spin being to diminish the drift, which increases as the angular velocity diminishes.

When the shell is filled the stability is slightly increased, and the spin need not be so great. For suppose a common shell, filled with powder of density 1·6; then, since α and γ depend only on the external shape of the shell, they have the same values as before, and

$$\alpha - \gamma = {\cdot}68184.$$

But $$\frac{\rho}{\sigma} = \frac{\text{weight of the displaced air}}{\text{weight of the shell}}$$

$$= \frac{\frac{4}{3}\pi a^2 c \times \frac{1}{816}}{\frac{4}{3}\pi a^2 c \left(1 - \frac{2^3}{3^3}\right) \times 7{\cdot}207 + \frac{4}{3}\pi a^2 c \frac{2^3}{3^3} \times 1{\cdot}6}$$

$$= \frac{27}{(19 \times 7{\cdot}207 + 8 \times 1{\cdot}6)\, 816}$$

$$= \frac{27}{149{\cdot}733 \times 816},$$

$$\log 27 = 1{\cdot}4313638,$$

$$\log 149{\cdot}733 = 2{\cdot}1753176,$$

$$\log 816 = 2{\cdot}9116902,$$

$$\log \frac{\rho}{\sigma} = 1{\cdot}4313638$$

$$- 5{\cdot}0870078,$$

$$= \bar{4}{\cdot}3443560,$$

$$\frac{\rho}{\sigma} = 0{\cdot}00022098,$$

$$k_1^2 = \frac{\frac{4}{3}\pi a^2 c \times \frac{1}{5}(a^2 + c^2)\left\{\left(1 - \frac{2^5}{3^5}\right) \times 7{\cdot}207 + \frac{2^5}{3^5} \times 1{\cdot}6\right\}}{\frac{4}{3}\pi a^2 c\left\{\left(1 - \frac{2^3}{3^3}\right) \times 7{\cdot}207 + \frac{2^3}{3^3} \times 1{\cdot}6\right\}}$$

$$= \frac{211 \times 7{\cdot}207 + 32 \times 1{\cdot}6}{19 \times 7{\cdot}207 + 8 \times 1{\cdot}6} \times \frac{1}{9} \times \frac{1}{5}(a^2 + c^2)$$

$$= \frac{1571{\cdot}877}{149{\cdot}733} \times \frac{1}{9} \times \frac{1}{5}(a^2 + c^2)$$

$$= \frac{1571{\cdot}877}{149{\cdot}733} \times \frac{2}{9} a^2, \text{ if } c = 3a;$$

and $$k_3^2 = \frac{1571{\cdot}877}{149{\cdot}733} \times \frac{1}{9} \times \frac{2}{5} a^2.$$

Therefore $$n^2 = \frac{\pi^2 k_3^4}{4a^2 k_1^2 \frac{\rho}{\sigma}(\alpha - \gamma)}$$

$$= \frac{\pi^2 \times 1571{\cdot}877}{9 \times 50 \times 149{\cdot}733 \times \frac{\rho}{\sigma}(\alpha - \gamma)}$$

$$\log \pi^2 = 0{\cdot}9943018,$$

$$\log 1571{\cdot}877 = 3{\cdot}1964249$$

$$= 4{\cdot}1907267,$$

$$\log 9 = 0{\cdot}9542425,$$

$$\log 50 = 1{\cdot}6989700,$$

$$\log 149{\cdot}733 = 2{\cdot}1753176,$$

$$\log \frac{\rho}{\sigma} = \bar{4}{\cdot}3443560,$$

$$\log (\alpha - \gamma) = \bar{1}{\cdot}8336825$$

$$= 1{\cdot}0065686$$

therefore

$$\log n^2 = 3{\cdot}1841581,$$
$$\log n = 1{\cdot}5920790,$$
$$n = 39{\cdot}09.$$

Similarly with filled double shell we shall find $n = 28$, about.

If the Martini-Henry bullet be considered a solid prolate spheroid of lead, of which the length is three diameters, then

$$\alpha - \gamma = {\cdot}68184,$$
$$\frac{\rho}{\sigma} = \frac{\text{density of air}}{\text{density of lead}}$$
$$= \frac{\frac{1}{816}}{10{\cdot}9} = \frac{1}{10{\cdot}9 \times 816}$$
$$k_1^2 = \frac{1}{5}(a^2 + c^2) = 2a^2,$$
$$k_3^2 = \frac{2}{5}a^2;$$

and therefore

$$n^2 = \frac{\pi^2 \times 10{\cdot}9 \times 816}{50 \times {\cdot}68184},$$
$$\log \pi^2 = 0{\cdot}9943018,$$
$$\log 10{\cdot}9 = 1{\cdot}0374265,$$
$$\log 816 = 2{\cdot}9116902$$
$$= 4{\cdot}9434185,$$
$$\log 50 = 1{\cdot}6989700,$$
$$\log {\cdot}68184 = \bar{1}{\cdot}8336825,$$
$$= 1{\cdot}5326525,$$
$$\log n^2 = 3{\cdot}4107660,$$
$$\log n = 1{\cdot}7053830,$$
$$n = 50{\cdot}744.$$

In the Martini-Henry rifle the rifling makes one turn in 22 ins.; and the calibre being ·45 of an inch, the rifling therefore makes one turn in $\cdot\frac{22}{45} = 49$ calibres.

Generally, for a projectile x calibres long, $\frac{c}{a} = x$, and therefore

$$a^3 C = \frac{2}{(x^2-1)^{\frac{3}{2}}} \log_\epsilon (x + \sqrt{x^2-1}) - \frac{2}{x(x^2-1)},$$
$$a^3 A = \frac{x}{x^2-1} - \frac{1}{(x^2-1)^{\frac{3}{2}}} \log_\epsilon (x + \sqrt{x^2-1});$$

and
$$\alpha - \gamma = \frac{A}{A+C} - \frac{C}{2A}$$
$$= \frac{2A^2 - AC - C^2}{2A\,(A+C)}$$
$$= \frac{2A+C}{2A} \times \frac{A-C}{A+C}$$
$$= \frac{\dfrac{2}{x}}{\dfrac{2x}{x^2-1} - \dfrac{2}{(x^2-1)^{\frac{3}{2}}}\log\,(x+\sqrt{x^2-1})}$$
$$\times \frac{\dfrac{x^2+2}{x\,(x^2-1)} - \dfrac{3}{(x^2-1)^{\frac{3}{2}}}\log\,(x+\sqrt{x^2-1})}{\dfrac{x^2-2}{x\,(x^2-1)} + \dfrac{1}{(x^2-1)^{\frac{3}{2}}}\log\,(x+\sqrt{x^2-1})}$$
$$= \frac{\dfrac{1}{x}\,(x^2-1)^{\frac{3}{2}}}{x\sqrt{x^2-1} - \log\,(x+\sqrt{x^2-1})}$$
$$\times \frac{\left(x+\dfrac{2}{x}\right)\sqrt{x^2-1} - 3\log\,(x+\sqrt{x^2-1})}{x - \dfrac{2}{x}\sqrt{x^2-1} + \log\,(x+\sqrt{x^2-1})}.$$

If the cavity be a similar spheroid of $\frac{1}{m}^{\text{th}}$ the linear dimensions of the external surface,
$$k_1^2 = \frac{\pi a^2 c\,\frac{1}{5}\,(a^2+c^2)\left(1-\frac{1}{m^5}\right)}{\pi a^2 c\left(1-\frac{1}{m^3}\right)}$$
$$= \frac{m^5-1}{m^5-m^2}\cdot\frac{1}{5}\,(a^2+c^2),$$
$$k_3^2 = \frac{m^5-1}{m^5-m^2}\cdot\frac{2}{5}\,a^2,$$

and
$$\frac{\rho}{\sigma} = \frac{\text{weight of shell}}{\text{weight of displaced air}}$$
$$= \left(1-\frac{1}{m^3}\right)\frac{\text{density of iron}}{\text{density of air}}.$$

Therefore, generally, we must have
$$n^2 = \frac{\pi^2\left(\dfrac{m^5-1}{m^5-m^2}\right)^2\dfrac{4}{25}\,a^4\dfrac{m^3-1}{m^3}}{4a^2\dfrac{m^5-1}{m^5-m^2}\dfrac{1}{5}\,(a^2+c^2)\,(\alpha-\gamma)} \times \frac{\text{density of iron}}{\text{density of air}}$$
$$= \frac{1}{5}\,\pi^2\left(1-\frac{1}{m^5}\right)\frac{1}{x^2+1} \times \frac{1}{\alpha-\gamma} \times \frac{\text{density of iron}}{\text{density of air}};$$

i.e.,
$$\frac{1}{5}\pi^2\left(1-\frac{1}{m^5}\right)\frac{1}{x^2+1}\times\frac{1}{\alpha-\gamma}\times\frac{\text{density of iron}}{\text{density of air}};$$

where $\alpha-\gamma$ is given by the formula above, giving n the number of calibres to one turn for the rifling at the muzzle of a gun firing shell of which the length is x calibres, and the cavity $\frac{1}{m}^{\text{th}}$ of the linear dimensions of the external surface.

The formula is obtained on the hypotheses that gravity is neglected, that the surrounding medium is frictionless and incompressible, and that the external surface of the shell is a prolate spheroid, and the results obtained agree fairly with what is observed in practice.

For instance, the Krupp 40^{cm} gun fires a steel shell 2·8 diameters long, and the rifling at the muzzle makes one turn in 45 calibres.

As the steel shell is to be employed against armour, we may assume that the linear dimensions of the cavity are one-half those of the external surface, as in our Palliser projectiles, and therefore $m=2$ and $x=2{\cdot}8$.

We have
$$\begin{aligned}
\sqrt{x^2-1} &= 2{\cdot}61534,\\
x+\sqrt{x^2-1} &= 5{\cdot}41534,\\
\log_\epsilon(x+\sqrt{x^2-1}) &= 1{\cdot}68924,\\
\frac{1}{x}(x^2-1)^{\frac{3}{2}} &= 6{\cdot}38890,\\
x\sqrt{x^2-1} &= 7{\cdot}32294,\\
\frac{2}{x}\sqrt{x^2-1} &= 1{\cdot}86810,\\
\left(x+\frac{2}{x}\right)\sqrt{x^2-1} &= 9{\cdot}19104,\\
\left(x-\frac{2}{x}\right)\sqrt{x^2-1} &= 5{\cdot}45484;
\end{aligned}$$

and therefore by the formula
$$\begin{aligned}
\alpha-\gamma &= \frac{6{\cdot}38890}{7{\cdot}32294-1{\cdot}68924}\times\frac{9{\cdot}19104-5{\cdot}06772}{5{\cdot}4548+1{\cdot}68924}\\
&= \frac{6{\cdot}38890}{5{\cdot}63370}\times\frac{4{\cdot}12332}{7{\cdot}14408} = {\cdot}654535;
\end{aligned}$$

and therefore
$$n^2=\frac{1}{5}\pi^2\times\frac{31}{32}\times\frac{1}{8{\cdot}84}\times\frac{1}{{\cdot}654535}\times 7{\cdot}8\times 816;$$

and working this out by logarithms, we shall find $n=45{\cdot}753$.

REPORTS

ON

MOUNTING OF HEAVY ORDNANCE

AT MALTA.

No. 2488.

DEP.-COM.-GEN. ORDNANCE,

In accordance with your orders, dated 28th ult., on War Office letter dated 21st ult. No. $\frac{\text{Malta, 5}}{4756}$, I beg leave to report that five 38-ton guns have up to the present time been received at this station, and have been delivered over to the Royal Artillery, as follows, viz. :—

Two at head of Calcarra Creek for Fort St. Rocco.

One at Ricasoli landing place for Fort Ricasoli.

Two at Jew's Sallyport (one for Fort St. Elmo, one for St. Lazarus' Bastion, East Valletta).

The carriages and platforms for these guns have also been given over to the artillery.

On arrival, the 38-ton guns were necessarily landed in the Dockyard, where is the only crane in the island capable of raising them. This is a crane worked by steam power—originally, I believe, equal to lifting 60 tons, but now limited to 40 tons.

From the Dockyard each 38-ton gun was brought to its destination on two iron flat-bottomed pontoons, borrowed from the Dockyard. These were firmly secured together, side by side, with chains, so as to form, as it were, one craft.

Across the decks, two baulks of timber, at proper distance apart, were fixed, so as to project some 6 ft. on the side the gun was to be landed, to serve as launching ways and to distribute the weight.

The special sleigh manufactured for moving these guns was placed on the baulks, in the centre of the decks, and a gun was lowered on to the sleigh and carefully secured with chains and wedges.

On reaching the point where the gun was to be landed—where arrangements had previously been made with a working party of Royal Artillery, with the requisite skidding, tackle, winches, &c., &c.—rollers were placed beneath the sleigh, when the guns were, in each instance, got ashore without difficulty.

H. TAYLOR,

D.-Com^{y}.

ORDNANCE OFFICE,
Malta, 3rd December, 1877.

From Major J. P. Morgan, Comdg. No. 15 Batt., 10th Bde. (late No. 3 Batt., 12th Bde.) R.A., to Lt.-Col. Jones, Comdg. Royal Artillery, Cottonera Division.

RICASOLI,

11th August, 1877.

SIR,

I have the honour to report for your information the completion of the duty of transporting the first 38-ton gun from Calcarra Creek to Ft. San Rocco.

The gun was landed on the 10th July, and was dismounted from the sleigh and placed in its position in rear of the pivot, 4 ft. clear of the racers, yesterday, the 9th August; so that exactly one month has been occupied in transporting this gun the distance of something over a mile along a roadway of considerable difficulty.

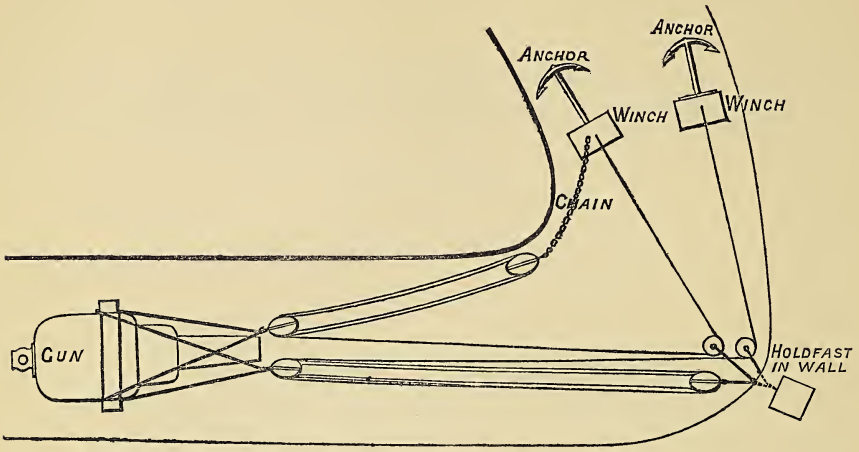
The number of days on which the gun was moved was 24, and the number of hours 110, or about 4½ hours per day. The average number of men employed was 77. Besides this, an average number of 37 men was employed for 51½ hours in shifting stores, shifting and fixing holdfasts, &c.

I enclose a diary of the operations, and time and number of men employed, in explanation of which I would submit the following observations. After landing, it will be observed that about four hours were occupied in slewing the gun at right angles; this, to a great extent, was due to the want of experience of the men in operations of this nature. At first, also, the progress was slow, as will be noticed on the 12th of July, when only a distance of 60 yds. was accomplished, over ground which was in all respects favourable. On this day, also, a Dockyard roller was broken, owing to the sleigh getting slightly to one side, when the weight was heaviest on this roller.

It is the only instance in which a roller was broken, but it tends to show what accidents are liable to happen if very great attention is not paid to the proper placing of the rollers.

It was attempted on the 13th to move the gun by a capstan, as being handier than the winch which was being used, but it was found the power was not sufficient, and the capstans were therefore discarded for this reason, and also from a knowledge of the fact that in most parts the road was so narrow that only a winch could be used.

On the 15th the gun was advanced up a steep incline. Care was taken to use two winches, with a sufficiently powerful tackle to each, and for this purpose a detachment of 31 men was obtained from No. 14 Batt., 10th Bde., (late No. 2 Batt., 12th Bde). The holdfasts were arranged independently of each other, so that if one gave way the other would hold. They were as under:—



On the 18th the difficult operation of slewing the gun round the narrow corner shown in the sketch was accomplished. The tackles shown in the sketch were used, being shifted as required to the breech or trunnion of the gun.

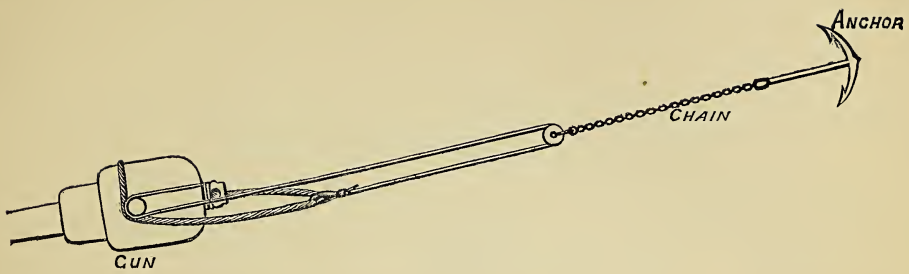
The progress next day was slow, owing to the necessity of shifting the holdfasts. After the gun was fairly started on the new direction on the 20th, considerable progress was made, mainly due to the use of oak planks on the top of the skids, whereby the friction was very considerably diminished. The same may be said of the 23rd, but on the 24th the progress was not so great, mainly on account of deficient power at the winch.

I accordingly requested some more men, and on the 25th the progress increased. This continued all the way to the top of the hill at the convent, when a turn to the left had to be made. Knowing by experience the time occupied in slewing the gun, I determined if possible to make it move round on its rollers by cutting them; and this operation was performed successfully on the same day, on which 90 yds. progress was made.

Moving towards San Rocco the slope was, for the two days, 30th and 31st, very easy, and the progress was satisfactory. As the road after that was tolerably smooth I discarded the skids, and continued the progress on two thicknesses of oak planks.

On the 1st of August, as the narrowest part of the road had to be passed, I shifted to the 6-ft. 10-in. rollers, and continued the remaining part of the journey on them. On some parts of the road there was only 6 ins. to spare on each side of the rollers. On the 3rd a rear holdfast had to be made, which was accomplished by using the anchor which had been passed.

The best tackle I found to use as follows:—



The standing end of a 6-in. rope was made fast to the gun by a sling, the running end was passed through a snatch-block made fast to the chain of the anchor, and then passed round the trunnion of the gun, and afterwards had two turns round the cascable. The man who stood at the breech could thus see when it was wanted, and had perfect control over the gun.

In ascending the slope of the glacis one anchor dragged, as it was in the new made soil of the glacis.

This shows that the anchors were not too large for this part. The difficulty was overcome by making fast the standing end of the fall to another holdfast on the roadway leading to the fort.

Another anchor also dragged near the gateway, owing to its being not sufficiently sunk in the ground.

On the 8th the gateway was very successfully passed without accident. It was done entirely by rollers, which at one time were so adjusted as just to pass the side with the trunnions rubbing on the wall, and had only, on one occasion, an inch or two to spare on the opposite side.

The gun was then run up in rear of the emplacement and parbuckled off on to skids, so as to have the vent uppermost. It now is on five skids in rear of the pivot, and 4 ft. clear of the racers.

I have the honor to be,

Sir,

Your most obedient Servant,

J. P. MORGAN, Major R.A.

Diary of the Operations of moving the 38-ton Gun to Fort San Rocco, showing the time and No. of N.C. Officers and Men employed.

Date. 1877.	Time employed.	No. of N.C. officers and men.	Remarks.
July 9th, Monday	From 5 to 8 a.m.	66	Removed stores from Ricasoli to Calcarra Creek by cargo boat. Removed heavy skidding from Ricasoli to Calcarra Creek by towage. Unloaded stores, winch, &c., from St. Elmo.
" " "	" 5 to 7 p.m.	66	Unloaded two anchors and 48 fathoms of chain from Dockyard lighter, and arranged stores.
" 10th, Tuesday.....	" 5 to 9.45 a.m.	69	Landed 38-ton R.M.L. gun; removed
" " "	" 9 to 11 a.m.	26	sling, hand, and trench carts from Ricasoli to Calcarra Creek.
" " "	" 5 to 7.15 p.m.	43	Unloaded cargo boat from St. Elmo with stores, and arranged stores.
" 11th, Wednesday..	" 5 to 9.45 a.m.	67	Slewed and advanced the gun 10 ft.
" " "	" 5 to 7.15 p.m.	32	Arranged stores, unloaded cargo boat from St. Elmo with stores.
" 12th, Thursday ...	" 5 to 9.45 a.m.	69	Advanced the gun 60 yds.; one Dockyard roller broke in centre.
" " " ...	" 5 to 7 p.m.	29	Arranged and unloaded stores, winch, &c., from St. Elmo, by drug.
" 13th, Friday	" 5 to 9·30 a.m.	67	Advanced the gun 48½ yds., and half-slewed her.
" " "	" 5 to 7 p.m.	28	Removed anchors, arranged and checked stores.
" 16th, Monday.....	" 5 to 9 a.m.	15,67,14,31	Advanced 25 yds., and half-slewed the gun; entered on steep ascent. Roadway blocked up.
" " "	" 5 to 7 p.m.	31	Removed holdfast, and arranged stores.
" 17th, Tuesday.....	" 5 to 9 a.m.	15,67,14,32	Advanced the gun up incline 35 yds. to the corner. She is now ready for slewing.
" " "	" 5 to 7 p.m.	48	Arranged stores, removed surplus stores to Fort Salvatore Store, removed guard tent and small stores in advance of gun.
" 18th, Wednesday..	" 5 to 9 a.m.	69	Slewed the gun round the corner without accident.
" 19th, Thursday ...	" "	69	Advanced the gun 32 yds. from the corner, received 22 oak planks 12′ × 17″ × 3″ from Com. of Ordnance.
" " " ..	" 5 to 7 p.m.	71	Removed holdfasts and winches. Arranged stores.
" 20th, Friday	" 5 to 9.30 a.m.	72	Advanced the gun 102 yds. Roads open at present.
" " "	" 5 to 7 p.m.	72	Arranged stores, and shifted holdfasts.
" 23rd, Monday.....	" 5 to 10 a.m.	67	Advanced the gun 116 yds.
" " "	" 5 to 7 p.m.	28	Arranged stores, shifted winches and holdfasts.
" 24th, Tuesday.....	" 5 to 9 a.m.	68	Advanced the gun up hill and round curve 72 yds.
" " "	" 5 to 7 p.m.	29	Arranged stores, shifted winches and holdfasts.
" 25th, Wednesday..	" 5 to 9 a.m.	15,69,14,22	Advanced gun up incline 101 yds.
" " " ...	" 5 to 7 p.m.	33	Arranged stores, removed holdfasts.
" 26th, Thursday ...	" 5 to 9.30 a.m.	14,21,15,68	Advanced the gun up incline 120 yds.
" " " ...	" 5 to 7 p.m.	31	Arranged stores.

(*Continued.*)

Date. 1877.	Time employed.	No. of N.C. officers and men.	Remarks.
July 27th, Friday	From 5 to 10.30 a.m.	14,21,15,70	Advanced the gun 90 yds., turned the corner of Capuchin convent. Hydraulic jack disabled. 22 fathoms of 6-in. rope broke off.
" 28th, Saturday ...	" 7 to 9 a.m.	40	Arranged stores, removed holdfasts.
" 30th, Monday.....	" 5 to 9.45 a.m.	14,21,15,69	Advanced gun 150 yds. Hydraulic jack disabled.
" " "	" 5 to 7.30 p.m.	30	Arranged stores, removed winches and holdfasts.
" 31st, Tuesday	" 5 to 10 a.m.	14,21,15,69	Advanced gun 180 yds., turned corner, and shifted from skids to planks.
" " "	" 5 to 7.30 p.m.	35	Arranged stores, removed holdfasts.
August 1st, Wednesday	" 5 to 9.30 a.m.	14,20,15,69	Advanced gun 150 yds. through lane way. Received 14 screws for winches.
" " "	" 5 to 7 p.m.	22	Arranged stores, shifted winches and holdfasts.
" 2nd, Thursday..	" 5 to 10 a.m.	60	Advanced the gun 160 yds.; turned the corner.
" " " ...	" 5 to 7 p.m.	58	Arranged stores.
" 3rd, Friday.....	" 5 to 10 a.m.	14,11,15,63	Advanced the gun 140 yds. along narrow road, mostly down hill.
" " "	" 5 to 7 p.m.	25	Arranged stores.
" 4th, Saturday...	" "	30	Removed holdfasts, conveyed stores from Salvatore to Ricasoli. Fort Salvatore cleared of stores. Key returned.
" 6th, Monday ...	" 5 to 10 a.m.	14,11,15,64	Advanced gun down and up hill 147 yds.; is now half-way up glacis of San Rocco. 17 fathoms of 6-in. rope broke off.
" " " ...	" 5 to 7 p.m.	29	Arranged stores.
" 7th, Tuesday ...	" 5 to 9.30 a.m.	14,12,15,68	Advanced gun 60 yds., entered road leading into fort 15 yds. Two anchors dragged.
" " " ...	" 5 to 7 p.m.	29	Arranged stores.
" 8th, Wednesday	" 5 to 9.30 a.m.	66	Advanced gun 68 yds., entered Fort San Rocco; is now close up to her position.
" " " ..	" 5 to 7 p.m.	32	Arranged stores.
" 9th, Thursday...	" 5 to 9.30 a.m.	67	Raised the muzzle, placed skids ready for parbuckling off sleigh.
" " " ...	" 5 to 7 p.m.	31	Arranged stores.
" 10th, Friday.....	" 5 to 10 a.m.	66	Dismounted gun off sleigh; placed it on five short skids in rear of pivot, 4 ft. clear of racers. Sent sleigh by men to Dockyard.

J. P. MORGAN,

Major R.A.

The Officer Comdg. R.A.,

Cottonera.

Return of Stores used in Transporting 38-ton M.L.R. Gun from Calcarra Creek to Fort San Rocco, showing the number of each expended. (R.A. Dist. Order, No. 2, 11. 12. 77.)

MALTA, 15th Dec., 1877.

Description.	No. used.	From dockyard	Expended.	Remarks.
Section II.—Tools, Entrenching.				
Axes, pick, helved	4	—	—	
Shovels, helved, universal	2	—	—	
Spades, helved, common	2	—	—	
Section III.—Tools, Artificers'.				
Hammers, handled: Claw, 20 ozs.	1	—	—	
Hammers, handled: Uphand, 7 lbs.	2	—	—	
Hammers, handled: Sledge, 14 lbs.	2	—	—	
Spanners, M'Mahon's	1	—	—	
Section IV.—Miscellaneous.				
Bars, iron, crow ... 6 ft.	2	—	—	
Blocks, wood, Bothway's: 18-in. treble	2	—	—	
Blocks, wood, Bothway's: 18-in. double	2	—	—	
Blocks, wood, Bothway's: 18-in. single	1	—	—	
Blocks, wood, Bothway's: 18-in. snatch	2	—	—	
Blocks, wood, Bothway's: 15-in. treble	2	—	—	
Blocks, wood, Bothway's: 15-in. single	1	—	—	
Blocks, wood, Bothway's: 12-in. double	2	—	—	
Blocks, wood, Bothway's: 12-in. single	1	—	—	
Cans, tin, oil, feeding ... quart	1	—	—	
Cordage, white, hawser, 3 strand: 6-in. ... 113 fms.	3	—	—	
Cordage, white, hawser, 3 strand: 4-in. ... 30 "	1	—	—	
Cordage, white, hawser, 3 strand: " ... 28 "	1	—	—	
Cordage, white, hawser, 3 strand: 3-in. ... 8 "	1	—	—	
Cordage, tarred, hawser, 3 strand, 2½-in., 1 "	40	—	13	
Covers, canvas, for sunshades	6	—	—	
Grease, Fenner's ... lbs.	7	—	7	
Yarn, spun, hemp	10	—	10	
Handspikes, common: 7-ft.	20	—	—	
Handspikes, common: 6-ft.	12	—	—	
Jacks, hydraulic, lifting, 30 tons	2	2	—	
Kegs, grease, No. 3 ... quarter	1	—	—	
Oil, mineral ... gals.	1	—	1	
Pins, iron, for sunshades	48	—	—	
Poles, tent, "	18	—	—	
Section V.—Ordnance.				
Buckets, wood, sponge, garrison	1	—	—	
Carts, with wheels: Hand, common	2	—	—	
Carts, with wheels: Trench	2	—	—	
Coins, wood: Large	10	—	—	
Coins, wood: Small	12	—	6	
Drugs, removing guns up to 5 tons	2	—	—	
Handspikes, naval, wood, 6-ft. and L.S.	4	—	—	
Levers, wood: 14 ft.	4	—	—	
Levers, wood: 12 ft.	1	—	—	
Limbers, complete, with shafts and wheels (dilly)	2	—	—	
Mauls, wood, iron-hooped, helved	12	—	—	

(*Continued.*)

Description.	No. used.	From dockyard	Expended.	Remarks.
Section V.—Ordnance.—(Continued.)				
Planks, wood. Fir ... 10′ × 17″ × 3″	4	—	—	
Fir ... 5′ × 17″ × 3″	1	—	—	
Oak ... 12′ × 17″ × 3″	22	—	—	
Oak ... 6′ × 12″ × 3″	6	—	—	
Oak ... 4′ × 12″ × 3″	7	—	3	
Stacking projectiles	4	—	—	
Plates, wrought-iron, 3′ × 7″ × ¾″	2	—	—	
Posts, picquet 8-ft.	10	—	—	
Posts, picquet 5-ft.	12	—	—	
Pile drivers, Swiss	1	—	—	
Rollers, wood, iron bound, for heavy sleighs. 8′ × 12″	7	4	—	Retnd. to Dockyard.
Rollers, wood, iron bound, for heavy sleighs. 7′ × 12″	4	—	—	
Rollers, elm 10′ × 6″	8	—	—	
Rollers, elm 6′ × 3″	4	—	—	
Ropes, drag, heavy, pairs	10	—	—	
Ropes, parbuckling 6-in. 18 fms.	2	—	—	
Ropes, parbuckling 4-in. 12 "	1	—	—	
Scotches, wood Large	20	—	20	
Scotches, wood Medium	20	—	5	
Scotches, wood Small	12	—	6	
Scotches, with handles, 12″ × 6″ × 6″	6	—	—	
Screws, iron, for wood	14	—	—	
Shackles, iron, with bolt and keep-pin	1	—	—	
Shackles, of sizes Large	1	—	—	
Shackles, of sizes Medium	2	—	—	
Shackles, of sizes Small	5	—	—	
Skids, wood Fir ... 23′ × 15″ × 15″	1	—	—	
Skids, wood Fir ... 22′ × 15″ × 15″	1	—	—	
Skids, wood Fir ... 20′ × 15″	1	—	—	
Skids, wood Fir ... 20′ × 12½″	1	—	—	
Skids, wood Fir ... 20′ × 9″	6	—	—	
Skids, wood Fir ... 14′ × 8″	6	—	—	
Skids, wood Oak ... 5′ × 5″ × 4″	4	—	2	
Skids, wood Oak ... 5′ × 6″ × 5″	1	—	—	
Skids, wood Oak ... 5′ × 15″ × 15″	6	—	1	
Skids, wood Oak ... 6′ × 12″ × 12″	17	—	1	
Skids, wood Oak ... 3′ × 9″ × 6″	17	—	12	
Skids, wood Oak ... 3′ × 9″ × 3″	12	—	4	
Skids, wood Oak ... 3′ × 6″ × 6″	14	—	8	
Skids, wood Oak ... 3′ × 4″ × 4″	12	—	8	
Skids, wood Oak ... 3′ × 3″ × 3″	10	—	6	
Skids, wood Oak ... 3′ × 6″ × 3″	9	—	6	
Slings, white rope 9″ × 16′	3	—	—	
Slings, white rope 9″ × 3′	1	—	—	
Slings, white rope 6″ × 10′	1	—	—	
Straps, white rope, 4-in.	1	—	—	
Tackles Heavy gyn	1	—	—	
Tackles Light "	1	—	—	
Tackles Gun	4	—	—	
Tackles Luff	6	—	—	
Anchors, 29 cwt.	2	2	—	Retnd. to Dockyard.
Chain 1-in. cable fms.	48	48	—	" "
Chain 1-in. "	12	—	—	
Chain ⅝-in. "	4	—	—	
Sleigh, service, special	1	1	—	Retnd. to Dockyard.
Wrenches, iron, knock up, G.S.	1	—	—	
Wedges, wood, long	17	—	—	
Winches, iron, double-purchase	2	—	—	

R. PIERCE, Mr.-Gr. R.A.

The Officer Comdg. R.A.,
Cottonera.

K. GAMBLE, Lieut. R.A.,
In Charge of S. District.

77

R.E. Office, Cottonera,

14th January, 1878.

Account of Work performed by the Royal Engineer Department in connection with the Landing and Transport of three 38-ton Guns—two to Fort San Rocco, the other to Fort Ricasoli.

A.—Transporting 38-ton Gun to Fort San Rocco.

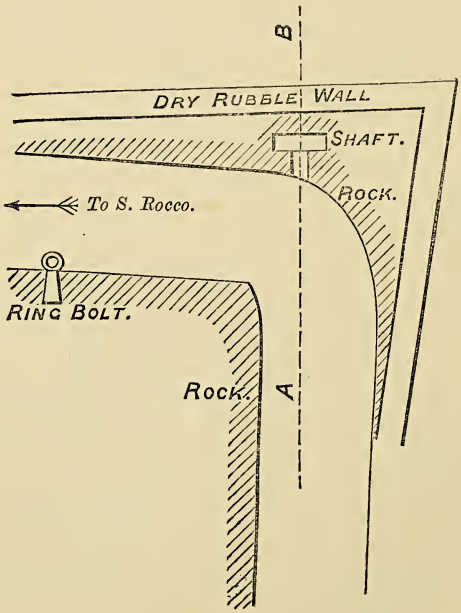
This gun was landed at the wharf near the gas works at Calcarra Creek, and transported thence by the road which leads past the Capuchin convent to Fort San Rocco.

The services performed by the R.E. Department were as follows:—

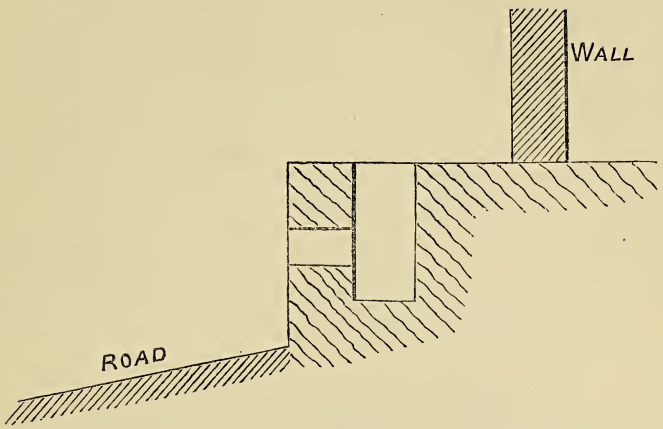
1. To assist in landing the gun, a hole 2′ 6″ × 1′ 6″ × 2′ 4″, was excavated in the floor of a private house (opposite to where the barge with gun was brought alongside the wharf), to receive the fluke of an anchor, to which tackle was made fast.

Compensation amounting to £1 10s. was made to the occupier of the house for the inconvenience and loss of time involved.

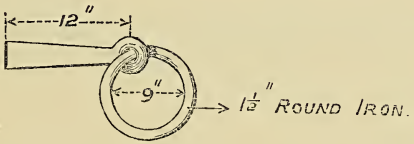
2. In transporting the gun to San Rocco from landing place, similar sized holes were made to receive anchors along the side of the road at distances apart varying from 50 to 150 yds.



SECTION ON *AB*.



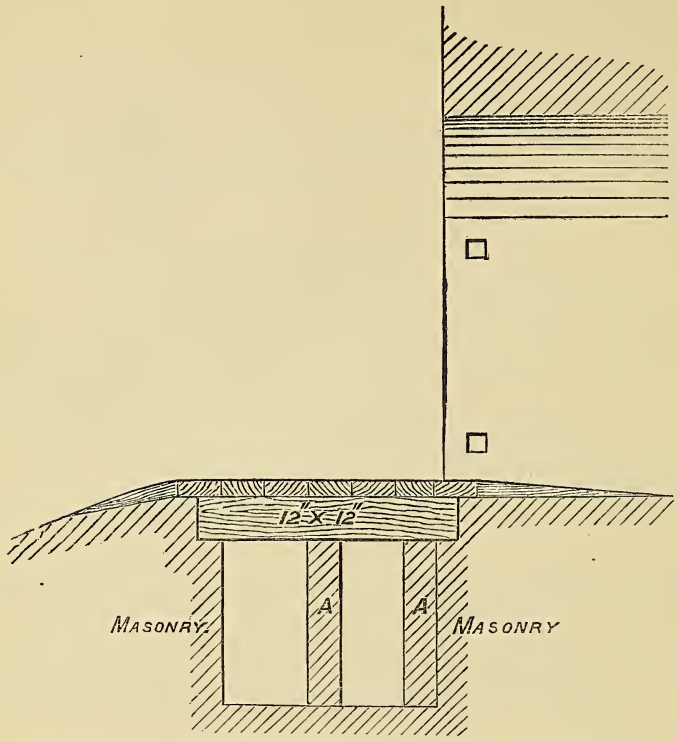
3. At the sharp and steep curve in road, near the gas works, a shaft was sunk in hard rock, and a horizontal opening made into it from face of rock. This allowed the large block through which part of the tackle was rove to be placed in it, and clear of the face of the rock, thereby giving more working space; a wrought-iron ring-bolt being fixed in the rock on the left hand side for securing tackle to.



4. The road from the Capuchin convent to within 300 yds. of the fort was levelled and repaired for nearly the whole distance by cutting down projecting lumps of rock, and filling up holes, so as to get an uniform width of 9 ft., and a solid bed for the skidding to rest upon.

5. At Fort San Rocco the iron gate, and handrailing at entrance, and also the portable drawbridge, were removed, so as to give sufficient width.

6. A temporary bridge across the ditch at entrance was made by building a wall in the centre of the drop-ditch parallel to the opening, 12″ × 12″ timbers, having a bearing at both ends and on the centre wall, being then placed across, and covered by 4″ planks placed transversely; the skidding upon which the gun was moved being placed on top by the Royal Artillery.



A, *A*, Temporary walls.

A.—The 2nd 38-ton gun was landed and transported to San Rocco in a similar manner, the whole of the operations being performed by the Royal Artillery.

B.—Transporting 38-ton Gun to Fort Ricasoli.

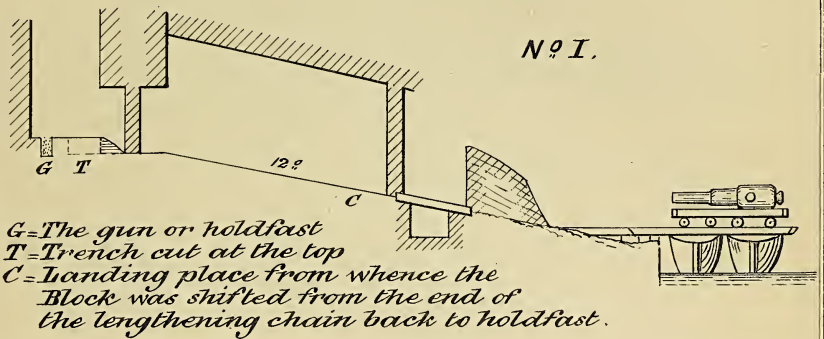
This gun was landed at the foot of the ramp at Rinella Bay leading to Fort Ricasoli, then moved up the ramp, and through the main entrance of fort to No. 1 Bastion. The services performed by the R.E. Department were as follows:—

1. One step at the bottom of ramp at landing place was removed, and a chase cut to receive the ends of skidding.

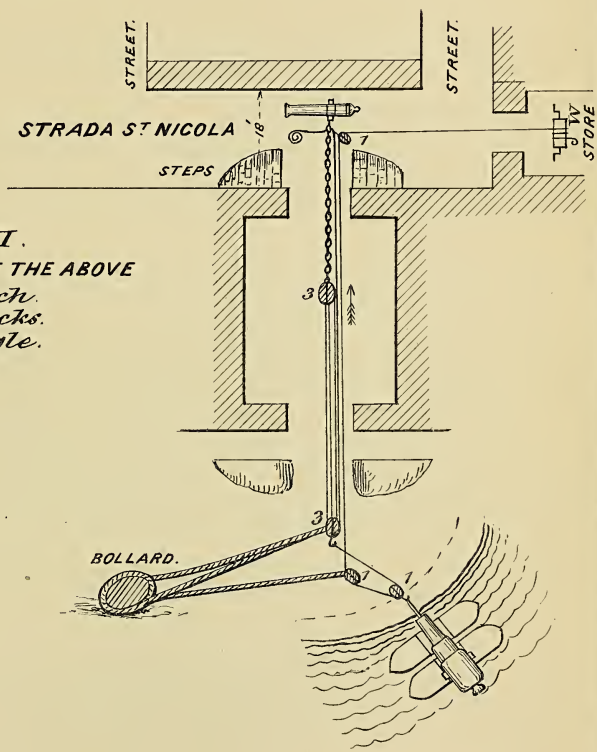
2. At the left side of the ramp a chase was cut to form a bollard in the rock, to which the tackle was made fast.

3. Additional shoving and bracing was fixed under the drawbridge. This was only adopted as a precautionary measure, the weight of the gun being actually carried by the skidding provided by the Royal Artillery.

SECTION OF JEWS SALLY PORT.



G=The gun or holdfast
T=Trench cut at the top
C=Landing place from whence the Block was shifted from the end of the lengthening chain back to holdfast.



Nº II.

ROUGH PLAN OF THE ABOVE

W = Winch.
3 = 3 Blocks.
1 = Single.

C.—Cost.

The total cost to the R.E. Department of transporting these two guns has up to the present been £13 2s. 6d.

Further expenditure will, however, be necessary for re-fixing the iron gate and hand-railing and bridge at Fort San Rocco, and for repairing injuries to works caused by the transport of the guns.

R. THOMPSON, Lieut. R.E.,

The Comdg. R.E.,
Malta.

D.O. Cottonera.

The Operation of Landing and Transporting a 38-ton Gun at the Jews' Sallyport, at Malta.

It being proposed to mount a 38-ton gun in St. Gregory's Bastion at Valletta, Malta, orders were given to disembark the gun at the Jews' Sallyport, as being more convenient than taking it round by any other way, though perhaps it is more exposed to the open sea than other places of disembarkation.

This sallyport has a couvreport immediately in front, on the pier; thence there is a steep ramp of 12° slope of steps through a passage, with another gateway at the top leading into a very narrow street, with another incline immediately at right angles up on to the level (*vide* Sketch Nos. I. and II.) Thence the gun had to travel a considerable distance until it reached Lower St. Elmo Gate, again make a sharp turn over a wooden drawbridge up a steep ramp along the ramparts to its destination.

The landing place being quite exposed, and having only 2½ ft. of water, one of the calmest days for disembarkation was chosen, in order to avoid damage to the pontoons (bringing the gun round) against the rocks by the rise and fall of the waves.

The gun was placed on two pontoons or barges by the navy, on a sleigh resting on two balks.

Preparations.—There was a landing place almost level for about 25 ft. The Royal Engineers had to cut a roadway 8 ft. wide through the couvreport, the drawbridge in front to be replaced by three stout beams, the lower gate widened from 6½ ft. to 7½ ft., and the crown of the arch from 6 ft. to 8 ft. high.

Since the gun was to be landed at 5.30 a.m. on the 24th August, all preparations were made on the 23rd inst. As no position suitable for a holdfast could be found at the top of the sallyport from which to attach the main tackle—all the houses, walls, and windows being too weak, and private

property—it was necessary to sink a 24-pr. S.B. gun at a depth of 5 ft. To this a stout chain was attached, and passed down as far as possible through the sallyport towards the sea.

On account of gas-pipes the gun could not be sunk nearer than 6 ft. to the walls.

The trench was well rammed and watered.

It was thought more advisable to place the winch and tackle where there would be no occasion for shifting again; consequently the winch was placed in a store near the holdfast in Strada St. Nicola, and the tackle (consisting of two treble 18-in. blocks* and 6-in. fall) had one block made fast to the chain, and the other, from which the running end came off, reaching down 20 ft. or so clear of the convreport. In case the gun could not be landed in a direct line with the sallyport, a bollard was cut in the soft rock, from which a strap was led to the lower block of the tackle, in order to keep it in its place. The running end of the fall was brought back to the holdfast, and made fast until the tackle should come into play. From the hook of the lower block a single return of 6-in. rope was led down through a single 18-in. block (which was made fast to the gun) and back through a leading block made fast to the same bollard, up to the holdfast, through a leading block attached there, and thence to the winch inside the store.

The working party consisted of Lieut. Coffey of my battery and 100 men.

August 24th.—At 5.30 a.m. the gun was brought round on two barges or pontoons, lashed together, mounted on a sleigh placed on two launching ways across the width of the pontoons, and projecting over the sides about 8 ft.

The pontoons were made fast fore and aft, so that the ways projected about 4½ ft. on shore. They could not be brought nearer, and had to be moored at an angle, owing to the rocks, which had been foreseen, as is shown by the above arrangement of tackle.

The gun was then mounted by one party on its sleigh, on four rollers, by means of 30-ton jacks (two).

Another party was told off to continue the roadway by means of 20′ × 15″ × 15″ fir skids, which as well as the launchways were carefully shored up. Another party to pass a sling round the gun, to attach the single block to.

The operation of placing the gun on rollers was carried out as follows:—The front was raised by the two 30-ton jacks sufficiently to allow of a 3-in. plank being placed under it; then the rear of the sleigh was raised the distance of 6 ins., which, together with the skidding the sleigh rested on, gave the height required. At the same time, the skidding was brought sufficiently to the rear as not to interfere with a roller being placed in rear of the carriage of gun. The weight was again taken by the jacks in front, and the front rollers passed under; the rear then raised, and the rear rollers passed under—viz. four altogether, the weight equally divided.

A couple of tackles as preventors were attached to the rear of the sleigh and manned, and all was ready to move. The winch was worked, and the

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* One treble and one double block would have answered.

gun came on shore. The time occupied in the actual landing, 1½ hours. Preparations, about 12 hours. In landing the second gun, the time of landing was about one hour only.

August 24th.—The gun in the afternoon was moved forward on the rollers on a roadway of planks, until it reached the block of the treble tackle; the single rope was then cast off, also the strap from the bollard, the main tackle lower block (treble) hooked on to the sling, and the running end of this tackle—which had been temporarily made fast to the holdfast—cast off and passed through the leading block at the holdfast, and thence on to the winch.

The move forward was continued through the couvreport over the three balks laid in place of the drawbridge, and rested immediately in the lower sallyport at the bottom of the ramp of 12°, on the level.

In order to pass this gate and roadway of couvreport the 8′ × 12″ rollers were changed to 6′ × 10″, and wherever the trunnions touched the stonework had to be cut away.

Time, 2 to 9 p.m.

August 25th.—The gun had to mount up the covered ramp of 12°, and as a heavy strain was expected, the sling (9-in.) was changed to a 12-in. one. As the men at the winch were obliged to work inside the store, and the detachment was much reduced—viz., to about 60 only—and the thermometer was about 95° in the shade, the gun made very slow progress up this incline, and the men were working from 2.30 till 8.30 p.m., when they reached the top, at which point the ground rises rapidly to about 20° into the Strada St. Nicola; and besides, owing to the narrowness of the street, and the tackle being chock-a-block, it was necessary to make another arrangement to get the gun through the gateway, which remained there that night.

August 26th.—Sunday.

August 27th.—Orders having been given to land another gun by our own party, preparations were made to do so. A great number of the stores had to be removed down to the landing place.

August 28th.—The tackle being, as above mentioned, chock-a-block, and there being only a gun's length between the gate and the holdfast, a tramway was cut from the sleigh with a small slope into the street. This was made level with 3-in. oak planks. The sling was shifted quite to the cascable of the gun and rear of sleigh, and shortened as much as possible, and the jacks were placed in rear to start it, and the gun was moved forward as before until just clear of the gateway by a few inches, or as far as it would go.

August 29th.—Long 15″ × 15″ skids were placed at right angles to the sleigh until flush with the side pieces, and well supported.

The gun was raised by jacks clear of the bed of the sleigh, being alternately lifted at the breech and muzzle.

Two 8-in. oak skids were placed under the short coil on the top of front fir skids, so as to keep the gun level, and the gun was then rolled off on to this roadway. (*Vide* Plate III.)

I may here mention an ingenious suggestion made by my subaltern, Lieut. Coffey, so as to furnish a holdfast for taking the gun up, by par-

buckling, the long incline leading into the bottom of St. Forni, whereby the tedious process of using anchors in the street was avoided. A sling-wagon with an 80-pr. gun attached was brought from St. Elmo and placed at the top of the incline, the wheels were well scotched, and the winch made fast to this holdfast. A parbuckling rope was used at first, the standing end made fast to the holdfast; but in order to ease the labour of the men at the winch, a single block was attached, and through this a rope was passed to the winch, the standing end being made fast to the holdfast. The roadway was made of two 20-ft. 15″ × 15″ fir skids; on the front one an 8-in. oak skid, well greased, being placed under the short coil. As we could only obtain two, only one could be placed at a time;* so that they were considerably worn in a short time. Thus the gun was kept level, and could be cut forward with tolerable ease.

In order to avoid halting every time the muzzle was to be cut forward, and also using a separate capstan, the following ingenious plan was adopted by Lieut. Coffey—viz., a tackle of a double and triple block was attached to a muzzle fid (the triple block next the muzzle), then the standing end was fastened to the main tackle block, and the running end to the parbuckling rope some feet beyond and secured; so that when the strain took as the gun rolled the muzzle was cut forward as far as required, and the running end of the tackle again cast off. The gun was parbuckled half up this incline.

August 30th.—The gun was parbuckled up to the top of Strada Nicola and bottom Strada Forni.

August 31st.—The 2nd 38-ton gun was landed. Working party as before. Time about our hour.

The preparations were the same, except that a crab capstan close to the landing place was used, by which to haul the sleigh on shore, and the gun was there left until the first gun was clear out of the way and the skids and planks could be spared.

In the afternoon the first gun was slewed round and moved forward about 10 yds.

September 2nd.—Sunday.

September 3rd.—Parbuckling was continued as before, using a single block, the parbuckling rope being attached thereto.

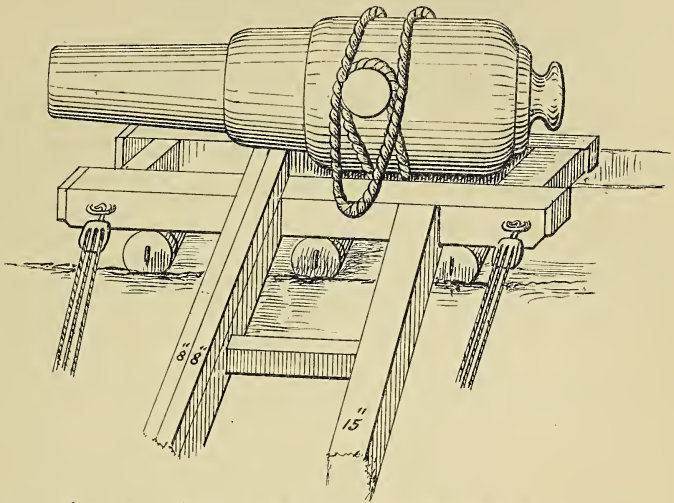
September 4th.—The gun was then placed on to short skids and left on the trench curtain out of the way of the traffic, until the second gun should be brought to the same spot, as it was necessary to clear the Jews' Sallyport as soon as possible. The drawbridge having been removed, and all traffic stopped, my men were therefore withdrawn for the second gun, which was brought up under Captain Wickham, after we had landed it.

Operations were not resumed at the first gun until the 20th September, when, being in command of the Valetta Division, Lieut. Coffey assumed charge, and the remainder of the journey was performed under his superintendence.

The second gun was brought up as far as the first gun under Captain Wickham's superintendence, and there left until it would be con-

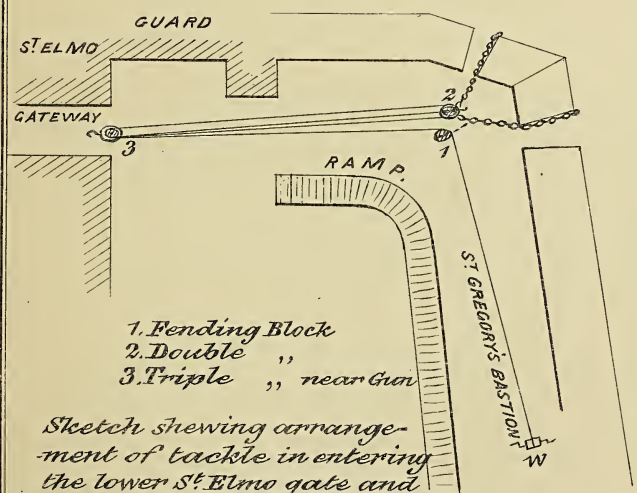
* Two of these 8-in. oak skids requisite.

SKETCH III.



Shewing position of the long skids for parbuckling off the Sleigh at the turn at the top of the Sally port.
Supporting skid of Gun not shewn herein.

PLATE IV.



1. Fending Block
2. Double ,,
3. Triple ,, near Gun

Sketch shewing arrangement of tackle in entering the lower St Elmo gate and to mount the Ramp.

venient to move it to its destination. As it would have been loss of time and no good gained to transfer the first gun on to the sleigh, and from which it would have been necessary to remove the second gun, the first was slewed to one side, and the second gun taken past it on its sleigh, moving steadily along on planks and rollers the length of the trench curtain on the 22nd and 24th September.

A crab capstan was used, with a single block at the gun, the standing end made fast to a convenient place along the wall, or to a 64-pr. R.M.L. gun on a standing carriage.

On 25th September it arrived at the corner. It had to curve round a quarter circle. This was done by cutting the rollers, and not by slewing the sleigh. The sling was shifted towards the breech, and a double and treble block used. The gun was now opposite Lower St. Elmo Gate, in a direct line to run through.

September 26th.—Shifted and prepared a holdfast for taking the gun over the bridge.

Tackle used.—One treble and one double block, with snatch for a lead; one iron winch.

As the Engineers found some difficulty in strengthening the bridge, from its weak foundation, and the expense being great, it was decided to use two old sheer spars, 45′ × 26″ across the bridge, which is 22 ft. wide, and take the gun across on them.

September 27th.—Placed the spars, and built an inclined plane of timber to take the gun up on to the spars, whose height, allowing for the projection, was 27 ins.

It was easier to run it up an incline than to raise it bodily by jacks, especially as the jacks could not be depended on. The incline was therefore built from the second roller to the level of the spars with old timber, &c.

The front of the sleigh was lifted by jacks, so as to allow of the top pieces of timber forming the incline being passed under the front roller.

A convenient holdfast was made inside the gate by passing a chain round the parapet contained between two embrasures; and as the holdfast was much higher than the gun, the upward pull lessened the friction.

Tackle used.—A triple and double block, running end passed through a leading block attached to the holdfast chain (*vide* Plate IV.), close to the standing block; the winch being worked clear on one side.

September 28th.—Completed the inclined plane. Took the gun up and across the bridge, and left it under the arch. The gun passed up the incline and over the spars without difficulty to the end. It had then to mount a very steep ramp. I considered that though the operation of building up would take longer, that it would be more advisable to run the gun up a temporary incline of timber from the head and top level of the spars to about two-thirds of the way up the ramp—as the steepness of the ramp would be thereby reduced—than if I let the gun come down off them. The incline was built of any available timber—such as old sides of platforms, &c., which the Ordnance Department gave permission to use.

September 29th.—Completed the above, and took the gun up the middle of the ramp, using the above tackle.

October 2nd.—Continued moving up the incline, and reached the level on the ramp of St. Gregory's Bastion; thence it had a straight level run into its emplacement in the salient of the bastion. Whilst moving along the level a power of two to one was used—viz., a 6-in. rope passing through a single block at the gun, the standing end made fast to a convenient holdfast in the works, these holdfasts being simply a piece of timber placed across the embrasure. The gun, on arrival, was left in its emplacement until the R.E. Department should be ready with the racers.

In conclusion, I beg strongly to commend Lieut. Coffey and the men engaged in the work—the former for his ingenious adaptation of the moveable holdfast, by which the laborious plan of using anchors, as was done in carrying out the operations in other districts, was avoided, and thus the streets had not to be cut up, and also for the above-mentioned plan for cutting forward the muzzle when parbuckling; and the latter for their cheerful endurance of the great heat whilst working for many hours together in the sun, and sometimes the working party consisting of only 50 men.

P. H. HARCOURT, Major R.A.,

Comdg. No. 17 Batt., 10th Bde., R.A.

Dec. 1877.

List of Stores used in Landing and Transporting a 38-ton Gun from the Jews' Sallyport to St. Gregory's Bastion.

Description of stores.	No.	Obtained from the dockyard	Remarks.
Axes, pick, helved	2	—	[to double.
Blocks { Treble	2	—	One of these was afterwards reduced
Blocks { Snatch	2	—	One obtained from Ordnance Store.
Cordage, white, 6-in. fms.	113	—	
Chain { 1½-in. "	—	24	
Chain { 2-in. "	3	—	
Fall of 6-in. white rope "	77	—	
Jacks, lifting, hydraulic, 30 tons	2	—	From Ricasoli.
Planks, 3-in. pieces	6 to 10	—	As they could be obtained.
Shovels, helved	2	—	
Scotches, with handles	6	—	
Sleighs, heavy, with rollers	0	1	
Skids.. { 20′ × 15″ × 15″	6	—	
Skids.. { 15″ × 15″	2	—	
Skids.. { 12″ × 12″	2	—	
Skids.. { 6′ × 9″ × 3″	6	—	
Sling-wagon (complete with sling)	1	—	
Slings { White, 6-in.	2	—	
Slings { " 12-in.	1	—	
Timber, old, a few pieces that were at hand; also six pieces of old platform	—	—	Expended.
Winches, iron	1	—	

P. H. HARCOURT,

Major R.A.

FORT RICASOLI, MALTA,
February 28th, 1878.

From Lieut. D. Radcliffe, R.A., to Officer Commanding Cottonera Division, Royal Artillery, Malta.

SIR,

I have the honour to send in, for the information of the Colonel Commanding Royal Artillery, Malta, the following report of the operation of moving the third (No. 15) 38-ton gun from Calcarra Creek to Fort San Rocco, and mounting it in its emplacement.

Wednesday, Feb. 16th.—Stores were brought from Fort Ricasoli to Calcarra Creek, including two anchors (13 cwt. and 9 cwt.) lent to us by the Royal Dockyard.

At 9 a.m. the gun arrived on two Dockyard lighters; the gun being mounted on a sleigh, across the lighters, which were lashed together. The lighters were brought close up to the wharf, and the gun, on the sleigh, was moved on rollers to the shore, muzzle to the front. The gun was then slewed on short rollers to the right, about a right angle, into the proper direction; the landing skids were sent back to Fort Ricasoli, and a guard placed on the gun and stores.

Sixty-three men were employed this morning, and were marched home about noon. The landing of the gun occupied about half-an-hour.

This work was performed under Captain Wickham, R.A.

In the afternoon 22 men were employed in bringing oak planks from St. Clement's Retrenchment to the gun, and in removing the small 3-ft. rollers used in slewing it.

Thursday, Jan. 17th.—Additional stores were brought up this morning from Ricasoli. The gun was moved 78 yds. to the front by a crab capstan and tackle, over level ground.

An anchor (13 cwt.) was used as a holdfast, but owing to recent rains it would not hold in the loose soil of the road. After several attempts at making an efficient holdfast, work was discontinued.

Forty-eight men were employed this morning, and worked for about four hours. After this date I was ordered to take charge of the operations.

Friday, Jan. 18th.—In the morning 32 men were employed in bringing additional stores to the gun.

In the afternoon I made a holdfast by placing an 18-ft. skid across the gateway of the gas works, having obtained the owner's permission. The gun was advanced by a winch up to this holdfast; total distance 34 yds., 15 of which were up an incline of 6°.

Great inconvenience was felt all through the operations on account of the shortness of the old pattern winch handles, as only two men could work on each handle.

Drag-ropes were fastened to the handles for other men to heave upon, but a great deal of labour would have been saved if the handles had been a foot longer.

Fifty-three men worked for four hours this afternoon in moving the gun.

Saturday, Jan. 19th.—The holdfast for the standing end of the tackle was shifted to a hole cut in the rock at the top of the steep and narrow piece of road past the gasworks. This hole had been cut by the R.E. for moving the two previous guns.

A snatch block was made fast to the same hole as a leading block, and took the running end of the fall to the winch, which was made fast to an anchor further up the road, round the corner, about 90°.

The slope varied from 7° to 10°.

The gun was left about 1 p.m. on a slope of 10°, being further secured by additional gun-tackles made fast to the hole in the rock above-mentioned, and by scotches in rear of the rollers.

The guard came on daily at the time work was suspended, and moved their tent forward to the gun. They were taken off every morning when the working party arrived.

Cart and horse traffic along the road was suspended by the civil power.

A heavy gyn-tackle was used going up this slope, treble block at the gun; and the work was necessarily slow, as I did not feel sure that the scotches would prevent the gun rolling back if anything broke, and had to take great care to keep the men out of dangerous positions. This part of the road is very narrow, and full of deep ruts caused by recent rains, which had to be filled up with earth for the planks to lie evenly.

Distance advanced, 31 yds. 52 men employed for four hours.

Monday, Jan. 21st.—The gun was advanced to the corner, and turned 90° to the left, by cutting the rollers. This had to be done with great precision, the road being very narrow and turn so sharp. Holdfasts were shifted and the gun moved to the front.

Slopes from 10° to 7°. Distance advanced, 73 yds. 62 men for four hours in morning, and 52 for four hours in afternoon.

Holdfasts were made on this and succeeding days by digging holes in sound parts of the road, and placing anchors in them; the standing end of the fall being made fast to one anchor, and the running end going to the winch, which was made fast to the other anchor.

We found after this day that planks one deep under the rollers were sufficient, instead of two deep as before, the road being better. This change lessened the labour of bringing up planks from rear to front of gun.

A two-to-one tackle was found sufficient after this.

Tuesday, Jan. 22nd.—Advanced gun 172 yds. up slope, beginning at 7° and then continuing at 3°. Weather very fine.

Worked for eight hours; two reliefs of 50 and 54 men respectively.

Wednesday, Jan. 23rd.—Advanced gun up slope of from 3° to 4°, 200 yds.

Two reliefs, 63 and 52 men respectively. Eight hours' work.

Thursday, Jan. 24th.—Advanced gun 184 yds. up slope of from 5° to 7°. The fall broke without any warning, but the rollers were well scotched up in rear.

Two reliefs of 52 and 55 men. Worked eight hours.

Friday, Jan. 25th.—Advanced gun 171 yds. altogether. Turned the corner to the left by the Capuchin convent (about a right angle) by cutting rollers. Incline from 2° to 4° up hill.

Eight hours' work. Two reliefs of 53 men each.

Saturday, Jan. 26th.—Advanced gun 39 yds., when a very heavy storm of wind and rain came on and turned the road into a mass of mud; so work was stopped and the men sent home.

Fifty-three men were employed for an hour-and-a-half. Incline 1° 30′.

Monday, Jan. 28th.—Advanced the gun 264 yds. along level ground. The lane at one part was very narrow, and great care was necessary to prevent men being jammed against the wall while bringing up planks and rollers from rear to front of gun.

Eight hours' work. Two reliefs of 53 each.

Tuesday, Jan. 29th.—Advanced gun 369 yds. down incline of from 1° to 4°.

A preventor rope, made fast to an anchor holdfast in rear, was used in descending the latter slope; two turns being taken round a trunnion, and slacked off as the gun was moved forward by the winch and single rope in front. (On level ground a single rope taken to winch from gun was found sufficient to move the latter forward.) Road broader, but still too narrow to be convenient.

Eight hours' work. Two reliefs of 67 and 68 men.

Wednesday, Jan. 30th.—Advanced gun down slope of from 2° to 10°. One piece was very steep, but the preventor rope as above described was found sufficient to check the gun. Then advanced up slope of from 2° to 6°.

The holdfast anchors being now placed in the made ground of the glacis of Fort San Rocco, gave out, and a good deal of time was lost in making an efficient holdfast.

This was done by making the standing end fast round the archway of the entrance to the fort, and the winch (with running end going to it) fast to two anchors, one behind another; these anchors being additionally secured by planks laid across them, the planks being held by picquets. Total distance advanced, 143 yds.

Two reliefs of 57 and 54 men. Eight hours' work.

Thursday, Jan. 31st.—Advanced to top of slope, shifted holdfasts and winch, and entered the entrance through glacis. The entrance being narrow and winding, the rollers had to be cut carefully.

Great inconvenience was felt all through the operations on account of the fewness and sponginess of the rollers, which were apparently made of unseasoned wood. Occasionally a roller would break to pieces, and then the sleigh would have to be raised by the hydraulic jacks, of which we carried two with us, and the roller removed.

Then, having so few rollers under the sleigh, the latter had to be halted every time a rear roller was brought to the front. This lost much time.

I was unable to procure any more rollers; there being, I believe, no more in the island. There ought to be seven rollers under the sleigh, and two extra; we were reduced to five under the sleigh, and none extra.

Total distance advanced to day, 130 yds. Eight hours' work; two reliefs of 54 and 54 men.

Friday, Feb. 1st.—Entered fort across bridge, which was built up underneath with skidding, and advanced through the archway.

This was an awkward turn, and required careful cutting of the rollers.

Turned the gun to the right by cutting the rollers; halted opposite emplacement; dismounted the gun off the sleigh by raising it by jacks on to skidding; parbuckled it on to emplacement, and left it about 3 yds. in rear of the racers, on skidding.

The Royal Engineers not having yet leaded down the racers, work had to stopped for the present.

Total distance moved, 53 yds. Eight hours' work; two reliefs of 53 and 52 men respectively.

Throughout the preceding operations I was assisted by Serjeant Wilde and Serjeant Jones, 10th Bde. R.A., late Serjeant Instructors in Gunnery to the late 12th Bde. R.A. I found their experience very useful in many cases, both having gone through the long course at Shoeburyness; and their ability and energy was all that could be desired.

Monday, Feb. 18th.—The racers being now leaded down by the Royal Engineers, work was resumed by us this morning. The gun was parbuckled on skids alongside the platform, and then raised about a foot. Worked from 9 a.m. till 3.15 p.m.

Wednesday, Feb. 20th.—Continued raising the gun. When high enough, parbuckled it on to platform on skids. Worked from 9 a.m. to 3.30 p.m.

Friday, Feb. 22nd.—Traversed the platform round 90°. Raised gun high enough for the carriage to go under it. Brought up carriage on to rear of platform. Slewed trunnions by gyn, and placed the latter for supporting breech of gun. Worked from 9 a.m. till about 2 p.m.

Saturday, Feb. 23rd.—Took the weight of the breech by the gyn; removed skidding from under breech. Moved carriage forward along platform under gun, the muzzle of which was supported by skidding on platform about 2 ft. in front of trunnions. Lowered gun into trunnion-holes.

In the operation of mounting the gun I was assisted by Serjt.-Major Brookman, No. 18 Batt., 10th Bde., R.A., and found him of great use and very efficient.

No man was injured during the whole of the work of moving the gun and mounting it.

The men worked very willingly and cheerfully all through, though the labour was at times very severe.

Appended are lists of stores and of those expended. Besides those shown as expended, there are other stores—such as rollers, blocks, &c. —injured, but not considered irreparable.

In addition to the inconvenience caused by the shortness of winch-handles and the fewness and sponginess of rollers, we wanted tarpaulins to cover tackles with at night, but could not obtain them.

I have the honor to be,

Sir,

Your obedient Servant,

D. RADCLIFFE, Lieut. R.A.,

In Charge of Operations.

Diary of the Operations of moving No. 15 38-ton M.L.R. Gun to Fort San Rocco, shewing the time and No. of N.C. Officers and Men employed and stores expended.

Date. 1878.	Time employed. From.	To.	No. of N.-C. O's. & men.	Stores expended.	Remarks.
Jan. 16th, Wednesday..	7.30a.m.	12.30p.m.	63	Skid. 3′ × 3″ × 3″, 1	Removed stores from Ricasoli to Calcarra Creek by handcarts; unloaded 2 anchors (9 and 13 cwt.) and 36 fathoms of 1″ cable chain from Dockyard lighter. Landed and slewed the gun; returned 2 skids (20′ × 15″) to Ricasoli by handcarts.
" " "	2 p.m.	3.30 p.m.	22	"	Removed 12 oak planks from St. Clement's Retrenchment to Calcarra Creek by handcarts; returned small rollers (3′) from Calcarra Creek to Ricasoli.
" 17th, Thursday ...	9 a.m.	1 p.m.	48	Skids. 3′ × 9″ × 3″, 1 3′ × 3″ × 3″, 1	Removed winch and 2 rollers (8′ × 12″) and short skids from Ricasoli to Calcarra Creek by handcarts. Advanced the gun 78 yds. on level ground.
" 18th, Friday	9 a.m.	1 p.m.	32	"	Removed winch and 1 coil of 6″ rope from Ricasoli to Calcarra Creek by handcart.
" " "	1 p.m.	5 p.m.	53	"	Advanced the gun 34 yds; 15 of them up incline of 6°.
" 19th, Saturday ...	9 a.m.	1 p.m.	52	"	Advanced the gun up incline 31 yds.
" 21st, Monday	9 a.m.	1 p.m.	62	"	Advanced the gun 73 yds. up incline of 7° to 10°; turned the corner of gas house.
	1 p.m.	5 p.m.	52		
" 22nd, Tuesday.....	9 a.m.	1 p.m.	50	Skid.	Advanced the gun 172 yds. up incline of 3°.
	1 p.m.	5 p.m.	54	3′ × 3″ × 3″, 1	
" 23rd, Wednesday..	9 a.m.	1 p.m.	63	Skids.	Advanced the gun 200 yds. up incline of from 3° to 4°.
	1 p.m.	5 p.m.	52	3′ × 9″ × 3″, 1 3′ × 6″ × 6″, 2	
" 24th, Thursday ...	9 a.m.	1 p.m.	52	Scotches.	Advanced the gun 184 yds. up incline of from 5° to 7°.
	1 p.m.	5 p.m.	55	Medium, 4 Small, 2	
" 25th, Friday	9 a.m.	1 p.m.	53	Skids.	Advanced the gun 171 yds., turned the corner of Capauchin convent; incline of from 2° to 4°.
	1 p.m.	5 p.m.	53	3′ × 9″ × 6″, 1 3′ × 9″ × 3″, 1 Scotches. Large, 2 Small, 2	
" 26th, Saturday ...	9 a.m.	10·30 a.m.	53	"	Advanced the gun 39 yds. of 1½° incline.
" 28th, Monday.....	9 a.m.	1 p.m.	53	Scotches.	Advanced the gun 264 yds.
	1 p.m.	5 p.m.	53	Large, 2	
" 29th, Tuesday.....	9 a.m.	1 p.m.	67	Skids.	Advanced the gun 369 yds. down incline from 1° to 4°.
	1 p.m.	5 p.m.	68	3′ × 9″ × 3″, 3 3′ × 4″ × 4″, 2 3′ × 3″ × 3″, 2	
" 30th, Wednesday..	9 a.m.	1 p.m.	57	"	Advanced the gun 143 yds. down incline from 2° to 10°, up incline from 2° to 6°.
	1 p.m.	5 p.m.	54		
" 31st, Thursday ...	9 a.m.	1 p.m.	54	"	Advanced the gun 130 yds.
	1 p.m.	5 p.m.	54		
Feb. 1st, Friday	9 a.m.	1 p.m.	53	Skids.	Advanced the gun 53 yds.; entered Fort San Rocco; dismounted gun off the sleigh. The gun is now supported on skids 3 yds. in rear of racers in No. 2 Emplacement.
	1 p.m.	5 p.m.	50	3′ × 9″ × 3″, 2 3′ × 4″ × 4″, 1 3′ × 3″ × 3″, 3	

R. PIERCE, Master-Gunner R.A.
D. RADCLIFFE, Lieut. R.A.,
In Charge of Operations.

The Officer Comdg. R.A.,
Cottonera.

Return of Stores used in Landing and Transporting No. 15 38-ton M.L.R. Gun from Calcarra Creek to Fort San Rocco.

MALTA, Feb. 1878.

Description.	No.	Remarks.
Section II.—Camp Equipment.		
Axes, pick, helved	2	Digging holes for holdfasts, &c.
Barrows { Hand, single	1	Carrying earth, stores, &c.
Barrows { Wheel, entrenching	2	" " "
Mauls, wood, iron-bound, helved	7	Cutting rollers.
Shovels, helved, universal	2	Digging holes and supporting planks.
Spades, helved, common	2	Digging holes and supporting planks.
Section III.—Tools, Artificers'.		
Hammers { Uphand, 7 lbs.	1	Cutting rollers, &c.
Hammers { Sledge, 14 "	2	Cutting rollers, &c.
Section IV.—Miscellaneous.		
Blocks, wood, Bothway's { Treble, 18-in.	2	
Blocks, wood, Bothway's { Double "	1	
Blocks, wood, Bothway's { Single "	1	
Blocks, wood, Bothway's { Snatch "	2	
Cans, tin, oil, feeding ..... quart.	1	Oiling winch.
Chain, 1-in. cable ..... fms.	48	Joining winch to holdfast
Cordage, white, hawser, 3 strand. { 6-in. ..... "	226	
Cordage, white, hawser, 3 strand. { 3 " ..... "	11	
Cordage, white, hawser, 3 strand. { 2 " ..... "	16½	
Cordage, tarred, hawser, 3 strand, 2½-in. ... "	16	
" yarn, spun, hemp ..... lbs.	3	
Grease, fenners ..... "	5	
Handspikes, common { 7-ft.	4	
Handspikes, common { 6 "	16	
Jacks, hydraulic, Tangy's, to lift 30 tons	2	Raising sleigh off broken rollers, &c.
Kegs, for grease, ¾ ..... whole	1	
Oil, mineral ..... quarts	2	
Section V.—Ordnance.		
Capstan, crab, complete	1	Moving gun along flat on first landing.
Carts, with wheels ..... trench	7	
Clinometers	1	Measuring slopes.
Limbers, complete with shafts and wheels	2	Transporting chains, &c.
Planks { Oak { 12′ × 17″ × 3″	16	Moving sleigh on.
Planks { Oak { 4′ × 12″ × 3″	6	Moving sleigh on.
Planks { Stacking projectiles 7′ × 12″ × 3″	4	Moving sleigh on.
Posts, picquet, garrison ..... 5-ft.	12	Holdfasts.
Rollers, wood { Oak, T.B. 8′ × 12″	9	On planks under sleigh.
Rollers, wood { Elm 6′ × 10″	10	On planks under sleigh.
Rollers, wood { Sabicu 3′ × 3″	6	On planks under sleigh.
Ropes, drag, heavy ..... pairs	6	Moving carts with stores, &c.
Scotches, wood { Large	16	Scotching up behind rollers.
Scotches, wood { Medium	20	Scotching up behind rollers.
Scotches, wood { Small	10	Scotching up behind rollers.
Scotches, wood { With handles	1	Scotching up behind rollers.
Skids, wood { Fir { 20′ × 15″ × 15″	2	Landing gun from lighters.
Skids, wood { Fir { 18′ × 12″ × 12″	1	Used as holdfast in a gateway.
Skids, wood { Oak { 6′ × 12″ × 12″	6	Used for miscellaneous purposes.
Skids, wood { Oak { 3′ × 9″ × 6″	5	Used for miscellaneous purposes.
Skids, wood { Oak { 3′ × 9″ × 3″	8	Used for miscellaneous purposes.
Skids, wood { Oak { 3′ × 6″ × 6″	10	Used for miscellaneous purposes.
Skids, wood { Oak { 3′ × 4″ × 4″	6	Used for miscellaneous purposes.
Skids, wood { Oak { 3′ × 3″ × 3″	8	Used for miscellaneous purposes.
Slings, white rope { 9″ × 16′	1	Holding winch to holdfast, tackle to gun, &c.
Slings, white rope { 9″ × 3′	1	Holding winch to holdfast, tackle to gun, &c.
Slings, white rope { 6″ × 10′	1	Holding winch to holdfast, tackle to gun, &c.
Tackles { Light gyn	2	Holding winches.
Tackles { Gun	2	Holding winches.
Anchors ..... 13 cwt.	1	Holdfasts in road.
" ..... 9 cwt.	1	Holdfasts in road.
Sleigh, service, special	1	Under gun.
Wrenches, iron, double-purchase	2	

R. PIERCE, Master-Gunner, R.A.,
D. RADCLIFFE, Lieut. R.A.,
In Charge of Operations.

Diary of Work carried on with the 38-ton Gun for St. Lazarus' Bastion, Malta, under the Superintendence of Lieut. Crofton, No. 15 Battery, 10th Brigade, R.A.

Date. 1877.	Time employed. From. To.	No. of Men.	Remarks.
Nov. 28th, Wednesday..	8.45 a.m. 11 a.m.	40	Rose the gun with two gyns 15″ on to skidding; placed sleigh under muzzle; arranged stores.
" 29th, Thursday ...	8.45a.m. 11.45a.m.	34	Rose the gun 18″; built up under muzzle with skidding; put sleigh under and lowered the gun.
Dec. 3rd, Monday	8.45 a.m. 11 a.m.	38	Lashed sleigh to gun; rose gun and sleigh together 16″; placed 3″ planks on 12″ rollers under; lowered gun and sleigh on to rollers.
" " "	1.45p.m. 3.30p.m.	29	Struck and returned two gyns—one to English Curtain, the other to St. Lazarus' Bastion, and arranged stores.
" 4th, Tuesday	8.45a.m. 11.40a.m.	17	Made two holdfasts with chains and skidding in embrasures; brought winch 10 yds., and lashed it; rose tackles.
" 5th, Wednesday...	8.45 a.m. 1 p.m.	29	Made roadway across bridge at Lower St. Elmo with 45′ × 20″ spars; advanced with gun 2 yds.; arranged stores.
" 6th, Thursday.....	8.45 a.m. 1 p.m.	24	Advanced with gun 40 yds. across bridge, turned corner; transferred from 20″ skidding to 3″ deal planks; removed roadway and arranged stores.
" 7th, Friday	8.45a.m. 11.15a.m.	50	Advanced with gun 40 yds., and shifted holdfast and capstan.
" " "	1.45p.m. 3.15p.m.	50	Advanced with gun 33 yds.; shifted holdfast and capstan, and arranged stores. One elm roller rendered unserviceable through constant use.
" 10th, Monday.....	8.45 a.m. 11 a.m.	27	Dug hole 3 ft. deep for holdfast; changed the direction of the lead; returned stores not in use.
" " "	1.45p.m. 3.45p.m.	45	Advanced with gun 22 yds., partly turned corner, and arranged stores.
" 11th, Tuesday.....	8.45a.m. 10.45a.m.	50	Shifted holdfast and capstan, turned corner, and advanced with gun 15 yds.
" " "	1.45p.m. 3.45p.m.	50	Advanced with gun 53 yds., shifted holdfast and capstan, and arranged stores.
" 12th, Wednesday..	8.45a.m. 11.20a.m.	56	Advanced with gun 76 yds., and arranged stores.
" 13th, Thursday ...	8.45 a.m. 11 a.m.	54	Shifted holdfast and capstan, and advanced with gun 56 yds.
" " "	1.45 p.m. 4 p.m.	54	Shifted holdfast and capstan, turned corner, and advanced with gun 42 yds.; arranged stores.
" 17th, Monday.....	8.45a.m. 10.40a.m.	38	Advanced with gun 41 yds.; shifted holdfast and capstan.
" " "	1.45p.m. 3.30p.m.	54	Advanced with gun 30 yds.
" 18th, Tuesday.....	8.45a.m. 10.40a.m.	35	Advanced with gun 24 yds.; shifted holdfast and capstan.
" 19th, Wednesday..	8.45a.m. 11.20a.m.	35	Advanced with gun 40 yds., and arranged stores.
" 20th, Thursday ...	8.45a.m. 11.30a.m.	44	Shifted holdfast and capstan, laid roadway, and advanced with gun 10 yds.
" 24th, Monday.....	8.45a.m. 10.45a.m.	28	Advanced with gun 10 yds., shifted holdfast and capstan.
" " "	1.45p.m. 3.15p.m.	50	Advanced with gun 15 yds.; arranged stores.
1878.			
Jan. 2nd, Wednesday...	8.45 a.m. 12 noon	50	Shifted the stores, holdfast, and capstan; advanced with gun up a steep incline 15 yds.

(*Continued.*)

Date. 1878.	Time employed.	No. of Men.	Remarks.
Jan. 2nd, Wednesday...	1.45p.m. 3.30p.m.	50	Advanced with gun up an incline 10 yds.; shifted stores across bridge.
" 3rd, Thursday.....	8.45a.m. 11.45a.m.	48	Advanced with gun across bridge 23 yds., and partly turned corner.
" " "	1.45p.m. 3.15p.m.	48	Shifted holdfast and capstan, turned corner, and advanced with gun 19 yds.
" 4th, Friday	8.45a.m. 10.45a.m.	46	Advanced with gun 23 yds., and turned corner.
" " "	1.45a.m. 3.30p.m.	58	Shifted holdfast and capstan; advanced with gun 20 yds., and turned corner into emplacement, ready for mounting, and returned stores.

R. M. CROFTON,

Lieut. R.A.

MALTA,
25th Jan., 1878.

Stores used for Transporting 38-ton Gun from 28th Nov., 1877, to 4th Jan., 1878.

Nature of store.	Size.	No. in use.	Remarks.
Blocks, wood, Bothway's { Single	18-in.	1	
Double	"	1	
Treble	"	2	
Snatch	"	1	
Crab capstan, complete	—	1	
Crabs, iron, double-purchase	—	1	
Handspikes, common, bevelled	7 ft.	4	
Planks, wood, moving guns. { Fir, whole	10′ × 17″ × 3″	11	
" half	4′ × 12″ × 3″	2	
Oak, "	10′ × 17″ × 3″	1	
Rollers, wood { Elm	6′ × 10″	5	
Oak, iron-bound	8′ × 12″	3	
Ropes, drag	Heavy.	4	
Skids, wood { Fir	20′ × 15″ × 15″	4	
"	45′ × 20″ × 20″	2	
Oak	3′ × 6″ × 9″	4	
"	3′ × 4″ × 4″	4	
Scotches, wood { Large	12″ × 6″ × 6″	8	
Small	—	4	
Sleigh, special, for transporting 38-ton guns	—	1	
Slings, white rope, gun	9″ × 16′	1	
" " "	9″ × 6′	1	
" 68-pr. gun	—	1	For holdfast.
Sling wagon	—	1	For holdfast.
Jacks, lifting, screw	—	2	
Gyns, complete, triangle	—	2	
" chain cables	—	3	For holdfasts.
" levers, wood	14′	1	
" " "	16′	2	
" " "	8′	1	
Hammers, sledge	—	2	
Pick and shovel	—	1	

MALTA,
25th Jan., 1878.

R. M. CROFTON,

Lieut. R.A.

Report upon Means used to Land two 12½-in. Guns at Sliema Pier, Conducting them to, and Mounting them at, Sliema Point Fort.

Water Transport.—The gun on sleigh rested on four 6′ × 9″ × 6″ baulks placed transversely on two long 18″ × 18″ Dockyard skids, which were thrown across two pontoons, lashed side by side. The pontoons were moored at the right-hand corner of the landing pier, by which means the largest straight pull could be obtained.

Roadway.—The long 18-in. skids jutted about 6 ft. over and 4 ins. above the pier. These were built up, so that on taking the weight of the gun a slope was formed of 1 in 72. Three 20′ × 15″ × 15″ skids parallel to one another, with long tapering wedges at the ends nearest the gun, were then so arranged that the gun should gradually be lowered until it was received at the bottom of the hill on 3-in. oak planks, which formed the only platform for the rollers to rest on while on the road. The planks were placed apart the breadth of the sleigh.

Holdfasts and Method of Moving.—Two anchors, of 9 cwt. and 13 cwt., were sunk horizontally in the solid rock below the roadway at distances about 50 and 120 yds. from the landing stage, the latter being at the top of the hill. A winch was used to move the gun, which was first placed at the first anchor then at the end of a 37½-fathom 1⅛-in. chain, stretched from the 2nd anchor, and then at the 2nd anchor a 6-in. well-worn fall was used for the hauling, worked with a double and single 18-in. block, attached to a sling cast over the gun and under the trunnions. The sleigh was raised by 20-ton jacks on to 8′ × 12″ oak iron-bound rollers, while still on the pontoons, and the baulks removed. A preventor rope was put round the cascable, but was hardly required. When the top of the hill was reached, a moveable holdfast, consisting of a 24-pr. gun slung on a sling wagon, the wheels being well scotched and helped by the weight of the chain, was found sufficient, and not to take long in moving it.

Time and Men.—On day of landing, 90 men in two reliefs of four hours were used; on other days from 60 to 80 in two reliefs were employed for four hours each. 16 men for the winch and 16 for the gun were, as a rule, ample; the others moving planks, rollers, &c. The first gun was landed and reached the fort in four days, the second gun in 3½ days. They would have been moved in a shorter time had not the rollers been of a very indifferent quality. At the top of the hill a very sharp turn of about 240° had to be made, to avoid going over a stone tank on the right of the road; and this proved the most difficult part of the operation.

Mounting.—Overhead gear was used as laid down in the instructions, the gun being gradually raised by jacks and skidding. When at the highest point it could be raised, the carriage was brought in and raised till the cap-squares could be pinned round the trunnions. The platform was then traversed as near under the carriage as possible. There great difficulty was

experienced, as the carriage hung so low, and had various fittings projecting from underneath. This, however, was gradually overcome by traversing both the platform and turntable at the same time in various directions.

Suggestion.—That the wrought-iron support to the washer-plates should be lengthened by at least one inch, being found in all instances too short.

W. CLARE SAVILE,

Lieut. R.A.

29. 10. 78.

List of Stores used in Moving and Mounting the 38-ton Guns at Sliema Point Battery.

Description.	No.	Remarks.
Anchors, complete { 13 cwt.	1	[at top of hill.
Anchors, complete { 9 cwt.	1	Placed about 120 yds. from landing place, Placed about 50 yds. from landing place.
Hammers, sledge	4	
Blocks, wood { Admiralty iron-bound snatch 18ins.	1	
Blocks, wood { Bothway's { Double, 18-in.	1	
Blocks, wood { Bothway's { Single, 18-in.	1	
Chain, iron, $1\frac{1}{8}$-in. link, with shackles ..... fms.	$37\frac{1}{2}$	
Cordage, white, hawser, 3 strand, 6-in. ..... fms.	226	
Handspikes, common { 7-ft.	4	
Handspikes, common { 6-ft.	6	
Shackles, large	2	Used with chain.
Crabs, iron, hoisting heavy guns	2	
Levers, wood, 14-ft.	2	
Planks, wood, oak, 12′ × 17″ × 3″	30	
Rollers, wood { Oak, iron-bound, 12″ × 8′	5	
Rollers, wood { Elm { 7″ × 3′	4	
Rollers, wood { Elm { 10″ × 6′	5	
Ropes, pairs, drag, heavy	4	
Ropes, gasket, tarred, 5-in.	1	
Scotches, wood ... { Large	12	
Scotches, wood ... { Medium	10	
Scotches, wood ... { Large, with handles	2	
Skids, wood, fir ... { 20′ × 15″ × 15″	4	
Skids, wood, fir ... { 20′ × 9″ × 9″	2	
Skids, wood, fir ... { 6′ × 12″ × 12″	11	
Skids, wood, fir ... { 4′ × 12″ × 12″	2	
Skids, wood, oak... { 5′ × 6″ × 6″	2	
Skids, wood, oak... { 3′ × 9″ × 6″	12	
Skids, wood, oak... { 3′ × 6″ × 6″	6	
Skids, wood, oak... { 3′ × 6″ × 3″	2	
Skids, wood, oak... { 3′ × 4″ × 4″	7	
Skids, wood, oak... { 3′ × 3″ × 3″	2	
Skids, wood, oak... { 10′ × 7″ × 7″	1	
Skids, wood, oak... { 6′ × 7″ × 7″	1	
Skids, wood, oak... { $4\frac{1}{2}$′ × 9″ × 6″	1	
Wedges, wood, oak, tapering. { 12″ × 6″ × 3″	16	
Wedges, wood, oak, tapering. { 15″ × 6″ × 3″	6	
Jacks, hydraulic, Tangye's { To lift 20 tons	4	*
Jacks, hydraulic, Tangye's { " 10 "	1	

Diary of the Work carried on with the second 38-ton Gun for Fort San Rocco, under the Superintendence of Capt. Rudge, No. 14 Battery, 10th Brigade, R.A.

Date. 1877.	Time employed. From. To.	No. of men.	Remarks.
Sept. 18th, Tuesday	6 a.m. 8 15 a.m.	75	Disembarked the gun and moved holdfast and winches.
" 19th, Wednesday.....	6 a.m. 9 a.m.	72	Slewed the gun round and advanced 18 yds., and transferred from long skids to planks.
" " "	5 p.m. 6.30 p.m.	72	Advanced 47 yds.
" 20th, Thursday	6 a.m. 9 a.m.	78	Advanced 55 yds.; arranged stores.
" " "	5 p.m. 6 p.m.		
" 21st, Friday	6 a.m. 9 a.m.	79	Gun taken round a curve and moved 30 yds. up a steep incline.
" " "	4.45p.m. 6.15p.m.	79	Gun advanced 14 yds. up the incline. Now ready for slewing.
" 24th, Monday	6 a.m. 9 a.m.	77	Gun slewed round and advanced 28 yds.
" " "	4.45p.m. 6.30p.m.	77	Gun advanced 32 yds.; winches and holdfasts moved.
" 25th, Tuesday	6 a.m. 11 a.m.	75	Advanced 57 yds. The two 30-cwt. anchors were put on a pontoon and returned to the Dockyard, two 12-cwt. anchors being received in their place. Also received 18 oak and 2 deal planks from Marina.
" 26th, Wednesday.....	6 a.m. 10 a.m.	81	Advanced 100 yds., and moved winches and holdfasts.
" " "	5 p.m. 6 p.m.	81	Advanced 58 yds.
" 27th, Thursday	5.45a.m. 9.30a.m.	78	Advanced 62 yds., moved holdfasts and winches, and arranged stores.
" " "	4.45p.m. 6.15p.m.	78	Advanced 44 yds.
" 28th, Friday	5.45a.m. 9.45a.m.	80	Advanced 95 yds.; moved holdfasts and winches.
" " "	4.45p.m. 6.15p.m.	80	Advanced 29 yds. Returned unserviceable planks to Ricasoli.
October 1st, Monday	S.R6a.mS.R10a.m	80	Advanced S.R. 50 yds.; moved winches and holdfasts.
" 2nd, Tuesday	6 a.m. 11 a.m.	75	Advanced 90 yds. and turned the corner at the convent. A short 9-in. rope sling missing, 3 ft. long.
" 5th, Friday.....	7.30a.m.12.30p.m.	47	Advanced 161 yds.; moved holdfasts and winches.
" 8th, Monday	7.30a.m 12.45p.m.	79	Advanced 165 yds.; moved holdfasts and winches. Changed from 12-in. oak to 10-in. elm rollers.
" 9th, Tuesday	8.15a.m.12.15p.m.	79	Turned a corner and advanced 172 yds.; moved holdfasts and winches.
" 10th, Wednesday..	8.15a.m.12.15p.m.	81	Turned corner and advanced 250 yds.; moved holdfasts and winches.
" 11th, Thursday ...	9 a.m. 11.30 a.m.	69	Advanced 54 yds.; moved holdfasts and winches; arranged stores.
" 12th, Friday	9 a.m. 12 noon.	68	Advanced 56 yds.; moved holdfasts and winches. Chain lashing of winch broke.
" 15th, Monday ...	9 a.m. 1 p.m.	71	Advanced 86 yds. up the glacis of the fort.
" 16th, Tuesday ...	9 a.m. 11.30 a.m.	71	Advanced 10 yds., and entered the road leading into the fort; moved winches and holdfasts inside; arranged stores.
" 17th, Wednesday..	9 a.m. 1.30 p.m.	69	Advanced 70 yds.; just inside the gate of the fort.
" 18th, Thursday ...	9 a.m. 4.30 p.m.	68	Advanced from the gate to No. 1 emplacement; raised the gun off the sleigh and parbuckled it into position.
			Total No. of days, 21.
			Total No. of hours, 92.
			Daily average, 4½ hours.
			Average No. of men, 74.

S. RUDGE, Captain R.A.,
No. 14 Battery, 10th Brigade, R.A.

29th Oct., 1877.

List of Stores used in Landing and Transporting the second 38-ton Gun to Fort San Rocco, Malta.

Description of store.	Size.	No.	Remarks.
Axes, pick, helved	—	2	
Anchors, 12-cwt.	—	2	Supplied from Dockyard.
Blocks, wood — Admiralty, iron-bound, snatch	18-in.	1	
Blocks, wood — Bothway's — Double	"	2	
Blocks, wood — Bothway's — Single	"	1	
Blocks, wood — Bothway's — Treble	"	1	
Cordage — Tarred yarn, spun ....lbs.	—	6	
Cordage — White hawser, 3 strand, coils of 113 fathoms	6-in.	2	
Crabs, iron, double purchase, for hoisting guns	—	2	
Chains, iron — Each 12 fathoms long	1-in. link.	4	Supplied from Dockyard.
Chains, iron — " 7 ft. long	$\frac{3}{8}$-in. link.	4	For securing winches to hold-fasts.
Grease, Fenner's ..... lbs.	—	4	
Handspikes, common, bevelled	7 ft.	12	
Hammers, sledge	14 lbs.	2	
Jacks, lifting, hydraulic, Tangye's	30 tons.	2	Supplied from Dockyard.
Lashings, tarred rope ....fms.	$2\frac{1}{2}$-in.	20	
Levers, wood	14 ft.	4	
Mauls, wood, helved, iron-hooped	—	4	
Planks, wood, moving guns. — Oak	12′ × 17″ × 3″	20	
Planks, wood, moving guns. — Fir	12′ × 17″ × 3″	2	
Posts, picket, garrison,	5-ft.	10	
Rollers, wood — Elm	6′ × 10″	10	
Rollers, wood — Oak, iron-bound	8′ × 12″	6	
Rollers, wood — Sabicu	$2\frac{1}{2}$′ × 5″	5	
Skids — Fir	20′ × 15″ × 15″	4	
Skids — Fir	5′ × 15″ × 15″	1	
Skids — Fir	6′ × 12″ × 12″	1	
Skids — Fir	14′ × 8″ × 8″	2	
Skids — Oak	3′ × 6″ × 9″	4	
Skids — Oak	3′ × 6″ × 6″	4	
Skids — Oak	3′ × 4″ × 4″	4	
Skids — Oak	3′ × 3″ × 3″	4	
Skids — Oak	3′ × 6″ × 9″	4	
Scotches, wood — Large	12″ × 6″ × 6″	18	
Scotches, wood — Medium	9″ × 5″ × 4″	12	
Scotches, wood — Handled	12″ × 6″ × 6″	2	
Sleigh, transporting guns over 12 tons.	—	1	Supplied from Dockyard.
Spades, helved, common	—	2	
Tackles — Luff, $2\frac{1}{2}$-in. tarred rope, 10 fms., 1 single and 1 double 8″ blocks	—	1	
Tackles — Gyn, $3\frac{1}{2}$-in. white rope, 16 fms., 1 double and 1 treble 10″ blocks	—	1	
Limbers, transporting, wood platform	—	2	Used for moving the anchors.
Slings, white rope, gun — With thimble...	9″ × 16′	1	
Slings, white rope, gun — " ...	9″ × 3′	1	
Slings, white rope, gun — " ...	6″ × 10′	1	

S. RUDGE, Captain,

Commanding No. 14 Battery, 10th Brigade, R.A.

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SHORT NOTES ON PROFESSIONAL SUBJECTS,

1867.

1. GUNPOWDER. An experiment was made by the O. S. Committtee in January at the instance of the Magazine Committee,* to ascertain at what distance the explosion of two barrels of gunpowder, each containing 100 lbs., would cause the explosion of other barrels. *Two* barrels were taken, that being the ordinary load of a barrow. The result was that at 40, 30, 20, and 10 yards the adjacent barrels were safe, but they were exploded at 5 yards. A barrel was found to be safe when well covered with wad-milltilt at 10 feet. Loose powder exploded at $7\frac{1}{2}$ yards and 10 yards, but not at 15 yards. The explosion was effected by electric tube from a magnetic battery about 500 yards off.

2. HALE'S 24-pr. ROCKETS of Royal Laboratory manufacture, were tried with very satisfactory results on the 18th January. The range at 15° was 1820 yards, with an average difference of each rocket from the mean of the whole of 133· yards, and a mean error of direction of 12·6 yards. The time of flight to this distance was about 9·8 seconds.

3. SNIDER CONVERTED ENFIELD RIFLES. The O.S. Committee were engaged throughout the month of January in investigating the cause of the bad shooting of some of these arms, which have exhibited a much greater susceptibility to small variations in the ammunition than was expected. The evil has been to a considerable degree removed by the employment of a lighter and shorter bullet, but it can scarcely be said that its cause is discovered.

AT 500 YARDS.	Mean radial deviation. Worst target. ft.	Best target. ft.	Average. ft.
20 Enfield rifles taken without selection from store gave	2·57	1·03	1·48
20 Snider rifles, Ammunition I. with 525 grain bullet ...	4·36	1·51	2·63
The same with Ammunition II. but also 525 grain bullet	6·56	1·21	2·78
The same with new Ammunition (called III.) with 480 grain bullet	3·27	0·87	1·46

There are however numerous anomalies to be explained, and the enquiry promises to be a long one; not the least perplexing of these is that the ammunition shot in April and May 1866, the success of which led to the decision of Government to proceed with the conversion, had the 525 grain bullet, which is now found in fault, and gave an average figure of 1·06 feet. The naval or short rifles supplied to all rifle regiments and to serjeants of infantry, continue to shoot well with the Pattern II. ammunition, giving a mean figure of about 0·81 feet at 500 yards. These figures of course refer to firing from fixed rests.

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* The Magazine Committee was appointed in November 1864 in consequence of the Erith explosion, to consider whether any steps are requisite to give greater security to the Government establishments, GENERAL SIR JOHN BURGOYNE, G.C.B., President.

4. Rifled 32-pr. bronze howitzer.* Proc. O.S.C., Vol. IV. p. 85. A series of experiments with a rifled 32-pr. bronze howitzer have been brought to a close. There are 40 or 50 of these pieces in store, and one battery of position equipped, in reserve; the object of the trial was to ascertain whether they could be prudently rifled, to fire on certain occasions the same shell as the M.L. 64-pr. gun, which has the same calibre of 6·30 inches. It was not contemplated to treat them wholly as rifled pieces and to supply them with 64-pr. shells *only*, but to continue the use of spherical common shells. Spherical diaphragm shells and common case shot from them on ordinary occasions, reserving the elongated shells for use in the attack of earthworks and fortified positions; and in certain exceptional circumstances in the field, for which their greater accuracy and large bursting charge might render them more effective than the spherical shells. The lightness of the piece, and an uncertainty in the lighting of the fuzes, have presented the only serious obstacle to this design. Its recoil on hard level ground with a charge of 2 lbs. 10 oz., and a shell of 64 lbs., when unchecked by any artificial means is 16 feet, that of the old field 24-pr. howitzer under the same circumstances being only 9 feet. In point of range it commands 1500 yards easily, is more accurate with spherical shells when grooved than before grooving, a common effect of rifling smooth-bores. Is of satisfactory precision as a rifled piece with the 64-pr. shell. Thus at 10°,—

	Range.	Error of range.	Error of direction.
	yds.	yds.	yds.
Rifled, with 64 lbs. shell, charge 2 lbs. 10 oz.....	1440	82	6·3
Unrifled, with 23 lbs. spherical shell, charge 3 lbs...	1778	185	17·5

no decision has been announced as to the adoption of the plan.

5. Museum of artillery. A noble model of Gibraltar constructed from the surveys of Lieut. Warren, R.E., under the superintendence of Major-General Frome, R.E., was received at the Rotunda on the 11th January. It is on a scale of 50 feet to 1 inch or $\frac{1}{600}$th, and gives details with a degree of accuracy and *vraisemblance* which must long make it one of the principal ornaments of that collection.

6. Extraordinary accident. A long term prisoner was killed at the Toomkoor jail, India, on the 15th Nov., 1865, in the following extraordinary manner:—

Some old guns and jingalls which had been lying time out of mind,† in the ancient Fort of Chenroy Droog, in the Kortagerry Talook, were brought in to the jail workshop for the purpose of utilizing the old iron.

One of them, a short wall-piece, about 2 feet long and $1\frac{1}{2}$ inch bore, was put into the forge, breech first. It suddenly exploded, and the man who was tending the fire, fell, when it was ascertained that an iron ball had passed completely through him, and had embedded itself, to the depth of 1 inch, in the mud wall of the workshop, 5 yards distant.

---

* The employment of the correct term bronze instead of brass, for gun-metal, which is an alloy of copper and tin, is of recent origin, and was first officially recognized in W.O. Circular N.S., No. 8, § 2140. It is the common military term of most languages,—

French, bronze.	Italian, bronzo.
Spanish, bronce.	German, bronze.
Portugese, bronze.	Dutch, bronzen.

American, bronze.

It is not at all necessary that it should replace "gun-metal" as a common term, or be substituted for "brass" in every application: particularly as many so called "brass" fittings are made of impure alloys which are not strictly bronze.

† Probably 70 years at least.

The bullet was of hammered iron, but was half eaten away with rust, and on examination of the jingall itself, it was found to be completely honeycombed and seamed by age and exposure, so much so that a man's finger could be in some places nearly embedded, the outside at the same time presenting very few traces of decay.

When the prisoner "Joogee" was killed, eleven others, who were also employed at and near the forge, were more or less wounded by large scales of rust being projected with the ball, the men presenting the appearance of being deeply pitted by smallpox.

On this occurring, the remaining matchlocks and wall-pieces were thoroughly examined, when another was found to be loaded. The powder was of country manufacture, and perfectly red. The gun that caused the fatal accident did not explode till it became cherry red; it was supposed to be one of Tippoo's make, and all that were brought in from Chenroy Droog Fort had the appearance of great age.

Chenroy Droog was one of Tippoo's forts, it is built of stone in chunam, is well constructed, has a stone wall surrounding its summit, and two lines of defence extending along the south and east faces well flanked with circular bastions and commanded by cavaliers, but not finished (like most of Tippoo's works) to the extent proposed.

A story is related in Upper Canada of a precisely similar occurrence some thirty years ago. An Irish settler had for years made use of an old gun barrel for stirring his fire, using as far as was known either end indifferently. The barrel however exploded one day and killed him. Several good stories were current in the Crimea of musket barrels used as fire bars behaving in the same way, where however the consequences where not so serious. Chemically the fact presents no difficulty, although gunpowder deteriorates by age principally because of its absorbing moisture, time produces no change in the ingredients themselves, and nothing short of the removal of the saltpetre from a powder charge would prevent it eventually exploding when heated in the manner described. The explosion of the store of gunpowder at Rhodes in 1857,—powder concealed from A.D. 1522 to A.D. 1827, and neglected until the accident occurred, is another instance that the sleep of this agent is not death.

7. TIME FUZES, THEIR RATE OF BURNING Two papers were printed in the third volume of these "Proceedings," pp. 15 and 259, on the influence of diminished atmospheric pressure upon the time of burning of a time fuze, leading to the general conclusion that a fuze at rest burns more rapidly, the greater the pressure; more rapidly for example at the bottom of a mountain than at the top, more slowly towards the summit of a lofty trajectory (as in mortar firing) than at either end; and the decrease in the rate of burning was determined to be 0·0011 of the whole time for —·0394 or 1 millimètre of barometric pressure, corresponding to about 33 feet of elevation near the sea level. That fuzes in motion should be similarly affected is a natural conclusion, and their rate of burning in shells of different forms and of different sizes, thus becomes in some measure a criterion of the relative pressures to which they are subjected by the resistance of the air. The more rapid the rate of burning the greater the pressure. The following average times of burning 1 inch collected from actual practice for the practical purpose of assigning rules for setting the fuzes, although they present several anomalies, and the direct effect is complicated by the different sizes of the shells or different volumes of air to be displaced, will be found to support this conclusion in the main, and shew the inaccuracy of the common rule that the fuze burns at an inch in 5 seconds nearly; every shell has its own rate. The initial velocity of the shell is stated. In the case of mortars it is the velocity due to the medium charge employed.

(1) Armstrong E time fuzes, meal powder composition :—

	Approximate mean initial velocity. ft.	Mean time of burning 1 inch in sec.
B.L. 20-pr.....	1150	1·85
" 12-pr.....	1180	1·93
" 9-pr.....	1030	2·10
" 6-pr.....	950	2·18

(2) Boxer's wood time fuze in elongated shells :—

	In B.L. shells.		In M.L. shells.	
	ft.	sec.	ft.	sec.
B.L. 7".....	1015	4·84	9".....1160	4·49
" 64-pr.	1120	4·71	8".....1180	4·56
" 40-pr.	1200	5·06	7"..... 1220	4·20
			64-pr....1120	4·55

(3) Boxer's wood time fuze in spherical shells :—

	ft.	sec.		ft.	sec.
10·5" (150-pr.)...	1640	5·56	68-pr....1791		5·21
10·0"	1257	5·49	32-pr....1912		4·94
8·0"	1465	5·19			

(4) Boxer's wood time fuze in mortar shells :—

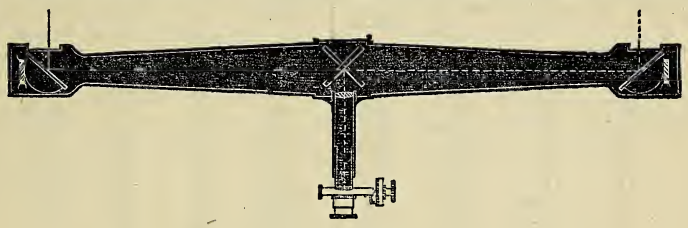
	ft	sec.
13".....	300 to 800	5·75
10".....	300 " 500	5·50
8".....	300 " 500	5·70

8. The Engineer of January, 1867, contains a series of articles by Mr Mallet "on the trajectories of elongated rifled projectiles on striking and in penetrating solid resisting media" based on two memoirs, the titles of which are not given, by Major-General Mayefski of the Russian service. A work whose pages are described as "in a perfect foam of formulæ," where "the highest analytical devices, elliptical functions, &c. are freely brought into play," will have few readers anywhere, and not many in the British service, in which high attainments in pure mathematics are rare as they are in most active professions of our eminently practical country. The conclusions however to which the writer and his annotator are led have a wider range of interest. We here find a theoretical refutation of the fallacy long supported by eminent mechanical authorities that flat-fronted shot are the best for penetration: on the contrary it is proved, according to Mr Mallet, "First, that *not only is the ogival form the best for penetrating armour plates when fired normally, but that it is the best for oblique fire at any angle.* Second, that directly contrary to the popular notion upon the subject, the ogival shot is much less likely to glance off in oblique fire than a flat-faced one of equal mass and diameter and equal velocity of projection, or than any form of round nosed shot." It furthur follows that "the ogival pointed shot may penetrate and not glance at angles of oblique fire more acute than half the vertex angle of the ogive: so oblique indeed that no spherical shot, much less any flat-ended cylinder would have a chance of delivering anything more than a glancing blow."

It scarcely requires the skill of a great analyst to predict in general terms what will happen when a pointed shot encounters an inclined surface which it is able to enter. The resistance in front and on the side of the angle of incidence, tends to throw over the rear part towards the side of reflection, and the axis tends more and more as it enters, towards a normal to the surface. This has been very well exemplified in several of the rounds fired at the inclined target at Shoeburyness, especially Nos. 1245, 1247, and 1293; the particulars will appear hereafter.

9. SMALL TELEMETER FOR MILITARY PURPOSES.* This instrument consists of a strong tube about 2 feet in length; at each end there is a small mirror placed at an angle of 45° to the axis of the tube, and in the centre two other mirrors crossing each other at right angles. A telescope with micrometer eye-piece is fitted into the centre of the tube.

Horizontal section of the Telemeter shewing the arrangement of the mirrors.



NOTE.—There is an opening in the centre of the instrument for direct vision, and for the purpose of illuminating the micrometer wires when using the instrument at night. All openings can be closed with shutters when required.

A prismatic compass is fixed on the top of the tube, so that the bearing, as well as distance, of any object can be at once determined.

The image of any distant object is reflected from each mirror at the ends of the tube (or base-line), to the mirrors in the centre, and from the latter into the telescope, thus giving two images of the object observed.

An opening is provided in the centre of the tube, above the mirrors, which enables an object to be seen by direct vision; this allows of the adjustment of each mirror to be made separately.

The instrument having been once adjusted so that the mirrors are parallel to each other, needs no further adjustment, but any deviation from parallelism must be frequently ascertained and applied as an index correction to the observed reading.

In this instrument the zero reading for 100 feet is 369, and any deviation from this is the index error.

The value of 1 division of the micrometer head is 11 seconds of arc.

This instrument will be found very useful for road surveying, as the distances can be determined with great accuracy up to 600 feet, and it can be used with tolerable certainty up to 3000 feet. To ensure correctness in the readings it must be carefully shaded from the direct action of the sun's rays, as they cause an unequal expansion of the tube.

A similar instrument, 6 feet in length, has been found to give good results up to 3000 yards.

NOTE.—Each observer must determine and apply his own index correction as it may vary with the focal length required by different eyes.

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* According to a design of Col. Clerk, R.A., F.R.S.

Observations taken with this Telemeter on the 19*th Nov.,* 20*th Nov., and* 19*th Dec.,* 1866.

Measured distance, feet.	Corrected readings, divisions.				Measured distance, feet.	Corrected readings. divisions.			
	*I. E. + 7	*I. E. + 4	*I. E. + 6	Mean.		*I. E. + 7	*I. E. + 4	*I. E. + 6	Mean.
50	724	726	723·5	724·5	750	60	61	60·5	60·5
100	369	369	369	369	900	52	50·5	51	51
150	251	252	251	251	1050	46	44	45·5	45
200	192	193	194·5	193	1200	42	40·5	41·5	41
250	156	157	158	157	1350	39	38	38	38
300	132	131	134·5	132·5	1500	36	36	34·5	35·5
350	115	115	115·5	115	1650	34	35	33	34
400	103	103·5	103	103	1800	32	33	31	32
450	94	90·5	92·5	92	1950	31	31		31
500	84	83	84·5	84	2100	29	29		29
550	77	76	78·5	77	2250	28	28		28
600	72	72	72	72	4500	21	22	21·5	21·5

* I. E.—Index error, as determined each day.

Table of Readings and Corresponding Distances.

Readings, divisions.	Distances, feet.	Readings, divisions.	Distances, feet.	Readings, divisions.	Distances, feet.	Readings, divisions.	Distances, feet.	Readings, divisions.	Distances, feet.	Readings, divisions.	Distances, feet.
369	100	260	143	150	261	88	474	66	665	44	1111
365	101	255	147	145	272	87	480	65	678	43	1146
360	102	250	151	140	283	86	487	64	691	42	1186
355	103	245	154	135	294	85	494	63	704	41	1226
350	104	240	157	130	307	84	501	62	718	40	1270
345	106	235	161	125	320	83	508	61	732	39	1318
340	108	230	165	120	334	82	515	60	747	38	1367
335	110	225	168	115	350	81	523	59	762	37	1420
330	112	220	173	110	366	80	530	58	778	36	1482
325	114	215	177	105	386	79	538	57	795	35	1544
320	115	210	182	100	410	78	546	56	813	34	1612
315	117	205	187	99	415	77	554	55	832	33	1690
310	119	200	192	98	419	76	563	54	852	32	1778
305	121	195	197	97	424	75	572	53	872	31	1873
300	124	190	203	96	430	74	581	52	894	30	1984
295	126	185	209	95	435	73	590	51	916	29	2109
290	128	180	216	94	440	72	600	50	939	28	2250
285	130	175	223	93	446	71	610	49	964	27	2412
280	133	170	230	92	451	70	620	48	991	26	2600
275	135	165	237	91	457	69	631	47	1019	25	2816
270	138	160	244	90	462	68	642	46	1048	24	3075
265	140	155	252	89	468	67	653	45	1079	23	3417

Note.—The table of readings is deduced from the three days observations.

10. CHALMERS' TARGET.* An experiment was made at Shoeburyness on 8th March, 1867, to test the power of resistance of this target to Palliser projectiles. For this purpose a 7″M.L. rifled gun of 7 tons was placed at 70 yds. from the target and at an angle of 60°. Five rounds were fired, viz. three shot of 114 lbs. weight each, and two shell of 115 lbs., charge 22 lbs. The result of the experiment was that the target, when struck on an undamaged portion, was not penetrated, thus confirming previous experiments which had shewn that the "Chalmers" target has greater power of resistance to projectiles than the "Warrior;" the latter having been penetrated by Palliser shot fired under precisely similar conditions. The striking velocity of the projectiles was about 1460′, and the energy about 78 foot tons per inch† of shot's circumference.

11. EXPERIMENTAL ARMOUR PLATE. A very interesting experiment was made at Portsmouth on 12th March 1867, to ascertain whether the addition of a proportion of steel would add to the resisting power of wrought-iron plates, to the impact of projectiles.

A plate $12' \times 4' \times 7''$ was manufactured by Messrs Cammell of Sheffield, of alternate thin layers of wrought-iron and steel, and was secured by through bolts to 42″ of timber. It was fired at on board H.M.S. "Thunderer" by a 68-pr. S.B. gun of 95 cwt. using a charge of 13 lbs.‖ and service cast-iron shot of 66½ lbs. weight, at 10 yards range, six rounds were fired, striking on a space of 20 square inches, and the result of these rounds was almost to detach this portion of plate and drive it into the backing to a depth of 4·5″.

Two rounds were then fired at the same range, but at an angle of 79°, from a 7″ M.L. rifled gun of 6½ tons, one round with 14 lbs.‡ and one with 22 lbs. charge,§ and Palliser shot of 114 lbs., the former buried itself in the plate and broke up, the latter *penetrated* the plate, drove the pieces into the backing, and broke off a large piece of the corner of plate ($1' \times 6'' \times 1'$) and threw it to the rear.‖ The welding of the plate seemed excellent, but cracks were developed after each round, as has ever been the case in firing at plates wholly or partially of steel, and its power of resistance was considered very inferior to that of an A1 wrought-iron plate, thus confirming previous experiments which have shewn that "no material for armour plates yet tested has been found to be equal to wrought-iron of the softest quality."¶

12. TRIAL OF 7-TON GUNS DESIGNED AS BROADSIDE GUNS FOR THE NAVY. This experiment took place on board H.M.S. "Thunderer" at Portsmouth, in July and December 1866. The following guns and shot were used:—

No. 1. 8″ M.L. shunt rifled gun 7 tons, firing hemispherical headed shot of Firth's steel, 150 lbs. with a charge of 30 lbs.

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* For description of this target, see Vol. III. p. 316, "Proceedings," R.A. Institution.

† This expression enables an easier comparison to be made of the effects of projectiles striking an object with different amounts of "*work*" than the more usual one of recording the result in foot lbs. It is thus obtained,

$$\frac{Wv^2}{2g \times 2240 \times 2\pi r} = \text{foot tons per inch of shot's circumference,}$$

in which W = weight of shot in lbs.; v, its velocity on impact; g, gravity; 2240 for conversion to tons; π, ratio of circumference.

‡ Service charge.

§ Battering charge.

‖ Equivalent to service charge at 200 yards.

¶ "Proceedings," R.A. Institution, Vol. IV. p. 435.

No. 2. 7″ M.L. polygonal rifled gun, 7 tons, firing flat-ended hollow shot of compressed steel, 133½ lbs. weight, 20 lbs. charge.

No. 3. 7″ M. L. "Woolwich" rifled gun 6½ tons, firing Palliser shot ogival headed, 114 lbs. weight, 22 lbs. charge.

The projectiles were fired at a 6″ wrought-iron plate backed by 42″ timber, at a range of 10 yards.

Result:—No. 1 gun. Striking velocity 1410′; foot tons per inch of shot's circumference 83. Punched a piece out of plate and drove it into backing, depth of indent 8¼″, shot broke up.

No. 2. Striking velocity 1280′; foot tons per inch of shot's circumference 71. Indent 5·5″ and bulged it behind, shot broke up.

No. 3. Striking velocity 1432′, foot tons 75, *penetrated through all.* Base of shot broke up, during penetration, head with point uninjured, weighing 22½ lbs., brought up by bulk head of ship.

The difference of results given by No. 1 and 3 is very remarkable, considering the much greater striking power of the former, viz. 83 against 75 foot tons, the superiority of the latter must therefore be entirely due to material and form of shot.

13. Expenditure of ammunition by the Prussian army during the campaign of 1866. The following information on this subject is extracted from Lieut.-Colonel Reilly's memorandum on the Prussian army in relation to the Campaign of 1866.

Infantry.* The greatest number of rounds fired during the war in the Second Army was 43 rounds per man. In the First Army, the three battalions of the 71st regiment at the battle of Königgrätz, expended about 72 rounds per man; but other regiments named only expended about 12 rounds per man, in the same action. The expenditure of infantry ammunition was, thus, very small. The actual expenditure of the First Army, Second Army, and Armies of the Elbe and Main, and of the detached corps in Silesia, of about 400,000 men was 1,854,000 rounds or between 4 and 5 rounds per man.

Artillery.† The reserves of the ammunition column were never called upon in action. The artillery of the Guards was engaged at:—

Burgersdorf; 4 batteries in action expended about 12 rounds per gun.

Königinhof; 3 batteries, under 12 rounds per gun.

Miscohlitz; 3 horse artillery batteries, 8 rounds per gun.

Königgrätz, 13 batteries, 1787 rounds.

The artillery of the Sixth corps d'armée expended at:—

Skalitz, 14 rounds per gun, two batteries being engaged.

Königgrätz, 21 rounds per gun, with ten batteries.

The first Corps:—

At Trautenau, 10 batteries expended under 12 rounds per gun.

At Königgrätz, 8 batteries expended 8 rounds per gun.

Total number of guns in action:—900; viz. 324, 4-pr. rifled; 234, 6-pr. rifled; 342, 12-pr. S.B.

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* Each soldier carries 60 rounds of ball cartridge, 40 in his pouch and 20 in his knapsack. The 1st reserve carries for grenadier and fusilier battalions, 22 rounds per man, for Jäger battalions 31 rounds per man. The 2nd reserve 120 rounds per man. The parks of the 3rd reserve should have a supply to make up the number of rounds up to 600 per man.

† The total number of rounds carried with each battery is as follows:—

6-pr. R. ...	limber	27 rounds	Total	114
	wagon	87 "		
4-pr. R. ...	limber	44 "	"	144
	wagon	100 "		
12-pr. S.B.	limber	24 "	"	111
	wagon	87 "		

The reserve ammunition averages 140 rounds per gun.

Total consumption of ammunition :—

4-pr. R. 22,548.....	Common shell ...	22,061
	Grape	78
	Shell*.....	409
6-pr. R. 8,663	Common shell ...	7,592
	Grape	9
	Shrapnel	864
	Shell*.....	198
12-pr. S.B. 4,988 ...	Common shell ...	4,130
	Grape	124
	Shrapnel	734

Lieut.-Colonel Reilly points out that "we cannot, as regards the artillery reserve any more than as regards the infantry, judge of the capabilities of the ammunition columns for keeping up the supply," as the reserve ammunition was never called upon in action.

14. Loss of men in the Prussian army during the campaign of 1866 :— Strength of armies invading Bohemia,—293,145 men of all ranks.

Loss at Königgrätz :—

	Officers.	Men.
Killed	75	1097
Wounded ...	249	6455
Contused.....	3	1817
	327	9369 or about $\frac{1}{23}$ of those engaged.†

Total loss in action during the war :—

Killed 2,910	
Wounded 15,554	Total 21,486.
Contused... 3,022	

15. *The new French rifled guns* for sea service. The *Revue Maritime et Coloniale* for February gives particulars of the new breech-loading guns of the French navy, accompanied by four engravings: some of the dimensions appear in the last edition of the "Handbook," at p. 329, but the following are more exact.

French breech-loading guns, 1866.

	Canon de ·27 rayé.	Canon de ·24 rayé.	Canon de ·19 rayé.	Canon de ·16 rayé.
Diameter of bore	10·82 in.	9·45 in.	7·64 in.	6·48 in.
Diameter of breech	44·6 in.	38·6 in.	30·4 in.	24·9 in.
Total length	15 ft. 3 in.	14 ft. 11 in.	12 ft. 6 in.	11 ft. 1 in.
Weight	21 t. 13 c.	13 t. 16 c.	7 t. 17·6 c.	4 t. 18·5 c.
Charge (ordinary)	53 lbs.	35·3 lbs.	17·6 lbs.	11·0 lbs.
Weight of common shot.....	310 lbs.	220 lbs.	115 lbs.	69·5 lbs.
No. of grooves	...	5	5	3
Range at 2°	...	1094 yds.	984 yds.	1039 yds.
" 10°	...	3937 yds.	3642 yds.	3827 yds.
" 35°	...	8525 yds.	7650 yds.	7924 yds.
Effective range against iron-clads said to be	...	1000—2000	800	500
With battering charge.....	66·2 lbs.	41·1 lbs.	27·5 lbs.	16·5 lbs.
Battering shot	476 lbs.	317 lbs.	165 lbs.	99 lbs.

These pieces are all of cast-iron of great length, strengthened externally by steel hoops as far as the trunnions, which are unusually far back. The twist is in every

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* Fire ball.

† Lieut.-Colonel Reilly gives the following for comparison :—

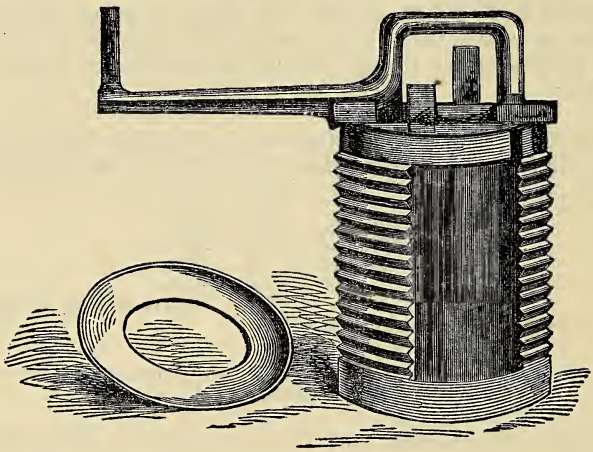
Losses of victors at

Waterloo	$\frac{1}{4}$	Inkermann ...	$\frac{1}{3}$
Borodino	$\frac{1}{3}$	Magenta ...	$\frac{1}{11}$
Talavera	$\frac{1}{8}$	Solferino ...	
Marengo	$\frac{1}{4}$	Königgrätz ...	$\frac{1}{23}$

case accelerating, beginning with 0° and terminating with 6° (1 turn in 30 calibres) at the muzzle. There are two projectiles,—common shells, with percussion fuzes, and solid steel shot: of the latter there are two varieties, flat-fronted for close quarters, pointed for more distant fire.

The annexed sketch of the breech screw, *vis de culasse*, and tin cup, *obturateur*, of the 9·4 inch gun will sufficiently explain the system of breech closing. The end of

Screw for closing the breech of the French rifled canon de ·24 (9·45 inch) with the tin cup.



the bore is tapped with a coarse female screw and closed with a solid screw plug; to facilitate the admission of the plug, the male and female threads are removed on three lines, over a width equivalent in each place to one-sixth of the circumference. Thus one-half of the thread is removed, and the projecting portion of the male thread passes along the space left by the cutting away of the female thread, until the plug is home, when a turn of 60° engages all the remaining threads and makes fast the breech. No advantage is claimed in respect to rapidity of fire, *La vitesse du tir serait au moins d'un coup en dix minutes*, a statement so modest, that we quote the words.

The guns are used on iron carriages and slides of the box girder construction, and very low. Those of the 9·4 inch gun weigh 6 tons 8 cwt. 6500 *kilo*, but can it is said be worked by 20 men at sea and by 14 in harbour. The system of compression seems to resemble our vice compressor, the friction being taken on the sides of the slide.

16. Rule for finding heights by the aneroid.* Multiply 26,300 by the difference between the readings of the aneroid, and divide the product by half the sum of the readings; the quotient will be the height uncorrected for temperature. To find the correction depending on the temperature:—Multiply the difference between 32 and half the sum of the temperatures at the lower and upper stations by 2·3 and by the *number of thousands of feet* in the uncorrected height. The product will be the correction, which must be added to or subtracted from the uncorrected height, according as half the sum of the temperatures is greater or less than 32.

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* Sufficiently accurate for any height, of less than 10,000 ft.—By G. Harvey Simmonds, Esq. [*Extracted from the Proceedings of the Meteorological Society*].

17. EXPERIMENTS MADE TO COMPARE THE RESISTANCES OF THE AIR TO CYLINDRICAL BODIED SHOT HAVING VARIOUSLY FORMED HEADS.* These experiments were made at Shoeburyness in September, 1866. The gun used was the 40-pr. M.L., the charge was 5 lbs. The shot prepared for the experiment were as follows :—

		lbs.
10 hemispherical headed, solid, average weight		39·34
10 hemispheroidal headed, solid	"	38·69
10 ogival (1 diameter), solid	"	39·56
10 ogival (2 diameters), solid	"	38·50
10 ogival (1 diameter), hollow	"	21·81
10 ogival (2 diameters), hollow	"	21·94
10 tubular shot		——

In the spheroidal head the ratio of the axes was nearly 1 : 2.

The firing was much interrupted by the passing of barges, and only 43 out of the 70 rounds could be fired in three days, although on one occasion 9 rounds were fired in 45 minutes. The experiments with the hollow ogival shot were extremely successful, as there were only two failures in the 20 rounds fired. For some reason the solid shot did not give nearly such good results as the hollow shot.

The Chronograph gave satisfactory records for the following number of rounds for the different kinds of shot, out of a total of 43 rounds fired :—

5 rounds of hemispherical head, solid.
4 rounds of hemispheroidal head, solid.
3 rounds of ogival (1 diameter), solid.
3 rounds of ogival (2 diameters), solid.
10 rounds of ogival (1 diameter), hollow.
8 rounds of ogival (2 diameters), hollow.

One round for each of the solid ogivals had to be rejected on account of the unreasonably large amount of resistance indicated. The records of the Chronograph were particularly good, so that the irregularity must have sprung from the unsteadiness of the shot. By using hollow and solid shot with the same charge of powder, considerable variation in initial velocities was secured.

The resistance of the air to each kind of shot clearly varied as the (velocity)^3 between the observed limits of 1100 f.s. and 1500 f.s., and this is the law indicated by experiments made with the 12-pr. B.L. to try the Chronograph in November and December, 1865.

The amount of pressure in lbs. exerted by the air against each form of shot was as follows :—

	lbs.		rounds.
To the hemispherical headed at a velocity 1250 f.s.	178·2	calculated from	5
To the hemispheroidal headed at a velocity 1250 f.s.	139·6	"	4
To the ogival headed (1 diameter), solid 1250 f.s.	147·9	"	2
" (2 diameters), solid 1250 f.s.	146·8	"	2
" (1 diameter), hollow 1500 f.s.	253·1	"	10
" (1 diameter), hollow 1250 f.s.	146·2	"	10
" (2 diameters), hollow 1500 f.s.	241·5	"	8
" (2 diameters), hollow 1250 f.s.	139·9	"	8

* Memo. by the Rev. F. Bashforth, B.D., relative to experiments with his Chronograph.

The mean height of the barometer was 30 inches, and the mean temperature 60·5° F. As the solid and hollow ogival shot (1 diameter) had the same external form, the pressure of the air resisting the motion of each at a velocity of 1250 ft. ought to be the same.

	lbs.
The mean of *ten* rounds of hollow shot (ogival, 1 diameter), gives	146·2
The mean of *two* rounds of solid shot " "	147·9

The solid and hollow ogival shot (2 diameters), had the same external forms.

The mean of *eight* rounds of hollow shot, ogival (2 diameters), gives	139·9
The mean of *two* rounds of solid shot " "	146·8

From the small differences in the amounts of the resistance of the air offered to ogival headed and spheroidal headed shot, it is manifest that, for practical purposes, it is not necessary to make any further experiments with the 40-pr. gun, except perhaps the remaining rounds might be fired when opportunity offered. It is probable also that the resistance of the air to any useful forms of heads for any other bore would not differ much among themselves.

The reason why the resistance of the air varies according to a higher power of the velocity than the second power may probably be found in increased volume of air disturbed by the increased velocity of the shot.

18. Lord Palmerston on the effect of the earth's rotation on projectiles. The following very curious letter was written by Lord Palmerston to the Earl of Dalhousie in December 1857, and by the latter referred to the officer whom he usually consulted at that period on subjects of gunnery, with the short and characteristic note,

"My dear ———

"Read and inform me on the abstruse philosophy of our Prime Minister, I wonder where we are to find a circular range of a mile radius.

"Ever yours,

"PANMURE."

It is now printed with Lord Dalhousie's kind permission, as a document pre-eminently interesting to artillerymen, and a more remarkable proof perhaps than many weighty state papers would afford, of the clear head of the great statesman. The subject must have been wholly new to Lord Palmerston. The letter suggests to us that somewhere in London society, he fell in with a person conversant with it, gave him his full attention, took a vigorous grasp of the question, revolved it in his own mind, and next day sat down in the midst of all his other avocations to suggest to his War Minister that experiment was required to determine the real amount of this new influence on projectiles. It was of course easy to satisfy Lord Panmure that the problem is one which does not require appeal to experiment at all. The effect is a necessary consequence of mechanical laws long since acknowledged as beyond dispute, and although it presents some difficulties when we

consider the case of projectiles fired east or west, it is so easy in the case of those fired north or south, that a few minutes explanation will convince any intelligent person of its reality (see "Proceedings," Vol. IV. p. 455). No experiments were made, but Lord Palmerston's letter may be added to the literature of the subject, as not the least curious illustration of the interest guns and gunnery possess for the active minds of our day. L.

December 20, 1857.

"My dear Panmure,

"There is an investigation which it would be important and at the same time easy to make, and that is whether the rotation of the earth on its axis has any effect on the curve of a cannon-ball in its flight, one should suppose that it has, and that while the cannon-ball is flying in the air impelled by the gunpowder, in a straight line from the cannon's mouth the ball would not follow the rotation of the earth in the same manner which it would do so if lying at rest on the earth's surface.

"If this be so a ball fired in the meridional direction, that is to say, due north or due south ought to deviate to the west of the object at which it was aimed, because during the time of flight, that object will have gone to the east somewhat faster than the cannon-ball will have done.

"In like manner a ball fired due east ought to fly less far upon the earth's surface than a ball fired due west, the charges being equal, the elevation the same, and the atmosphere perfectly still. It must be remembered however that the ball even after it has left the cannon's mouth will retain the motion from west to east which it had before received by the rotation of the earth on whose surface it was, and it is possible therefore that except at very long ranges the deviations above mentioned may in practice turn out to be very small, and not deserving the attention of an artillery-man.

"The trial might easily be made in any place in which a free circle of a mile or more radius could be obtained, and a cannon placed in the centre of that circle, and fired alternately north, south, east, and west, with equal charges, would afford the means of ascertaining whether each shot flew the same distance or not.

"Yours sincerely,

"PALMERSTON.

"It has been ascertained that the rotation of the earth produces a sensible effect on the oscillating pendulum."

19 Photo-Lithography as practiced in the Royal Carriage Department, Woolwich.* The process is the same in principle as that of photo-zincography, invented by Colonel Sir H. James, R.E., but is specially worked out in its details to suit the particular subjects upon which it is employed in the above department. Such subjects being chiefly line drawings of artillery material; the lines being very fine, and the details so small and intricate, that unless very sharply rendered in the reduced photo-lithographic copy they would be unintelligible.

As in the photo-zincographic process, a mixture of gelatine and bichromate of potash on sheets of paper is used as a medium for receiving and transferring to stone

* By Mr H. Butter, chief draughtsman, Royal Carriage Department.

the lines, dots, &c., by which the drawing is represented; 3 oz. of the best gelatine are dissolved in 40 oz. of hot water, and 2 oz. of bichromate of potash in 10 oz. of hot water; the two are mixed together and kept liquid while in use by means of a hot water dish. The paper, of a thin tough description, is coated but once with a mixture by being floated on it for about five minutes, and after drying spontaneously is hot pressed to give it a smooth fine surface.

The drawing to be reproduced is stretched on a board and a photographic negative taken of it in the usual way; perfect transparency should be carefully maintained in the lines, &c. A sheet of the prepared paper is then placed under the negative in an ordinary pressure frame and printed in a subdued light.

A very thin layer of lithographic re-transfer ink is rolled on a clean polished stone, and the print is laid face downwards on it and passed through the press; on removal it is placed in a dish of rather hot water and allowed to soak until the black ink yields to the touch, the water is then poured off and a supply of hot gum water added with which by means of a clean soft sponge the face of the print is washed; the black ink on the soluble parts of the composition, or those unaltered by light, are rubbed away leaving the drawing behind. Several changes of warm water are necessary to remove the gum and dirt, and a soft sable brush used (while the print is still immersed in the warm water) to cleanse out all the minute details and brush away whatever scum of ink remains.

When dried it is damped on the back and laid face downwards on a slightly warmed polished stone, and passed once only through the press; it is then worked up as an ordinary transfer and may be printed in the same manner and to the same extent as ordinary drawings on stone.

The negatives are taken in the Photographic Department of the Royal Arsenal, all the other parts of the process are performed in the Royal Carriage Department.

The whole of the large series of lithographs produced in the Royal Carriage Department are in course of being reduced to a smaller size by this process, a specimen of which can be seen at the R.A. Institution.

Cost of small size (coloured) 3d. each.

20. EXPERIMENTS ON THE PENETRATION OF IRON ARMOUR PLATES BY STEEL AND CHILLED IRON PROJECTILES.* The steel shot were all *hemispherical* headed, and the chilled shot *ogival* headed.

It requires about 28 ft. tons per inch of shots circumference to send either a hemispherical headed steel or an ogival headed chilled shot through a $4\frac{1}{2}$ inch unbacked wrought-iron plate. About 42 ft. tons per inch are required for a $5\frac{1}{2}$ inch plate.

From these experiments the following *practical* conclusions may be drawn when the projectiles are fired *direct*.

(1) An unbacked wrought-iron plate will be perforated with equal facility by solid steel shot, of similar form of head, and having the same diameter, provided they have the same *vis vivâ* on impact; and it is immaterial whether this *vis vivâ* be the result of a heavy shot and low velocity, or a light shot and a high velocity, within the usual limits of length, &c. which occur in practice.†

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* Recently carried out under the direction of the Ordnance Select Committee, and are referred to in a "*Report on the penetration of armour plates by steel shot, &c. by Capt. W. H. Noble, R.A. London, Longman and Co.*

† If the elongated shot be of excessive length this comparison will not hold good, as there will be a waste of "work" in altering the dimensions of the shot itself; 2·25 diameters is about the limit of length.

(2) An unbacked iron plate will be penetrated by solid steel shot, of the same form of head but different diameters, provided their striking *vis vivâ* varies as the diameter nearly, that is, as the circumference of the shot.

(3) That the resistance of unbacked wrought-iron plates, up to 5·5 inch, to absolute penetration by solid steel shot, of similar form, and equal diameter, varies as the square of their thickness, nearly.*

(4) These experiments have proved that, although in the case of cast-iron a light projectile moving with a high velocity will indent iron plates to a greater depth than a heavier projectile with a low velocity, but equal "work" or "energy," it is not as necessary that there should be a high velocity when the projectiles are of a hard material such as *steel* and *chilled iron*, and this result will be much in favour of rifled guns, by enabling them to prove effective with comparatively moderate charges.

Experiments shew that it takes the same amount of *energy* to send hemispherical headed steel shot and ogival headed chilled shot through 4·5 inch and 5·5 inch plates fired at under similar conditions.

When, however, the wrought-iron plates are backed by wood the ogival headed chilled shot has an advantage, in the proportion of about 10 to 9.

That is to say, suppose it required an *energy* of 1000 ft. tons to perforate the "Warrior" with a hemispherical headed steel shot; the same effect would be accomplished by 900 ft. tons in the case of an ogival headed chilled shot of the same diameter.

Sufficient experiments have not yet been made to enable us to determine with accuracy the effect of shot with different shapes impinging obliquely on an iron structure.

Allusion has been made in previous "Occasional Notes" to General Mayefski's work on this subject.

Our experiments, however, do not entirely bear out General Mayefski's conclusions.

Chilled projectiles almost invariably break up on impact, and the consequent loss of work does not appear to have been taken into account by General Mayefski. On the whole it has been found that practical conditions are satisfied by assuming that when shot strike obliquely the *energy* lost for purposes of penetration is in proportion to the sine of the angle of incidence.†

Experiment has shewn that it requires an *energy* of about 60 ft. tons per inch of shot's circumference to send a hemispherical headed steel shot through the "Warrior," the fire being direct. The same effect will be produced by 54 ft. tons per inch in the case of an ogival headed chilled projectile.

If the angle of incidence be 60°, the hemispherical headed steel shot requires about 81 ft. tons per inch and the chilled shot 73 ft. tons per inch.

From Captain W. H. Noble's Report it appears that the flat-headed form is one of the worst that could be used for the penetration of armour plated vessels either in direct or oblique fire.

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* This is only true when the plates are of the best quality. It is well known that it is easier to make a thin than a thick plate, and that the latter is liable to imperfect welding in the process of rolling. The manufacture of armour plates has, however, been so much improved of late, that it is practically allowable to assume that their resistance varies as the square of their thickness.

† That is, the shot striking in a slanting direction may be supposed to have opposed to it a plate of a thickness equal to the diagonal formed by the line of direction.

21. Experiment which took place at Shoeburyness on the 7th May last,* in presence of the Ordnance Select Committee, the Superintendent of Experiments, and many other officers.

The carriage is constructed on the box girder principle, the sides being formed of two half-inch iron plates with a space of 4½ inches between them.

The gun was elevated and depressed by means of the usual elevating arcs which were securely clamped by a screw. India-rubber buffers were fitted to the rear of the carriage to ease the shock should it recoil to the end of the platform.

The compressors, which worked very well, acted by means of an axle fitted with right and left-handed screws.

On the gun recoiling both compressors acted together; they can be used either as self-acting by means of a trip plate on the platform, or set each time by hand.

The front of the platform was fitted with *one* truck only in the centre, the sides being supported by two iron props with flat shoes which slide along the front racer. There was no difficulty whatever in traversing.

A 9-inch muzzle-loading rifled gun of 12 tons was mounted on the carriage, and 40 rounds were fired, during the afternoon, with battering charges of 43 lbs. and elongated shot of 250 lbs.

The gun was fired for rapidity with the ordinary detachment for 12 ton guns.

The gun being laid accurately each round at targets from 1200 to 2000 yards distant.

The first 5 rounds, for rapidity, were fired in 6 m. 30 sec.

The second 5 rounds in 5 m. 15 sec.

The gun at the conclusion of each 5 rounds was easily traversed to extreme points right and left by four men.

The practice throughout was excellent.

At the conclusion of the trial the universal opinion was that the working of both carriage and platform was most satisfactory.

22. Various facts connected with the attack of iron defences.

(1) The 9″ muzzle-loading rifled gun of 12 tons fired direct at 200 yards with a Palliser shell of 250 lbs. and charge of 43 lbs., has completely perforated an iron structure composed of 8″ solid armour plates resting on eighteen inches of teak backing and a ¾″ iron skin; in fact, an 8″ plate on "Warrior" backing.

When the above projectile struck obliquely at an angle of 60° it failed to penetrate.

(2) The above gun fired with a similar projectile, and reduced charge of 23 lbs. has completely perforated an ordinary "Warrior" target, consisting of a 4½″ plate on eighteen inches of teak, and a ⅝″ iron skin. Range 200 yards.

(3) The 7″ muzzle loading rifled gun of 7 tons, fired direct at 70 yards with a Palliser shell of 115 lbs., and reduced charge of 13 lbs. has completely perforated an ordinary "Warrior" target.

When the above projectile struck obliquely at an angle of 60°, it failed to penetrate although the charge was increased to 20 lbs. With a full charge of 22 lbs. a solid Palliser shot penetrated at an angle of 60°.

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* Trial of a wrought-iron garrison sliding carriage and dwarf traversing platform for 12 ton guns, supplied by Sir Wm. Armstrong and Co.

23. Iron plate experiments. The following extract from a letter addressed by the Russian Minister of Foreign affairs to the British Ambassador will be read with interest:—

St Petersburg,
Le $\frac{17}{29}$ Mai, 1867.

M. le Vice Chancelier n'a pas manqué de placer sous les yeux de S. M. l'Empereur, et de transmettre à M. le Ministre de la guerre, le remarquable rapport du Capitaine Noble sur l'action comparative de differents projectiles, que V. E. a eu l'obligeance de lui communèquer par la note du $\frac{13}{25}$ Mars, 1867.

C'est avec le plus vif intérêt que l' aide-de-camp Général Militaire a accueilli ce travail, si digne à tous égards de fixer l'attention des hommes spéciaux, et il se fait un plaisir, conformément au désir exprimé par V. E. de mettre à la disposition du Gouvernement Britannique le résultat des différentes expériences faites en Russie avec des canons se chargeant par la culasse, ainsi que deux mémoires du Général Major Mayefski, qui traitent de l'influence rotatoire des projectiles sur leur force d'impulsion.

The memoirs of General Mayefski (of the Russian Committee of Artillery), above referred to, are,—

(1) *De l'influence du mouvement de rotation sur la trajectoire des projectiles oblongs dans l'air*, pp. 183 : extracted from Vol. V. of the *Revue de Technologie Militaire*, 1865.

(2) *De l'influence du mouvement de rotation des projectiles oblongs sur leur trajectoire dans les milieux solides*, pp. 105 : extracted from the same work. This latter is the paper reviewed by Mr Mallet in the "Engineer" of January 1867, as noticed *ante* No. 8.

24. Erosion of the bore of rifled guns firing battering charges. The effect produced upon the upper surface of the bore of a rifled gun firing battering charges is to produce a disintegration of the metal which shews itself first in narrow longitudinal striæ, such as might be produced by a comb of unequal teeth moved irregularly. These longitudinal markings are next connected by very fine transverse lines at right angles to them, at tolerably uniform intervals, giving a reticulated appearance to the whole surface. Then as firing is continued the longitudinal channels deepen and become more and more irregular, the gas eating out cavities of rounded section and irregularly connected, until after 400 or 500 rounds, a gutta-percha impression exhibits deep irregular channels diversified with lumps and knobs that at a little distance resemble the bark of a tolerably rugged tree more than anything else. It will be easily seen that this effect depends almost entirely on the amount of the charge. The quantity of gas trying to escape between the upper surface of the shot and the bore of the gun increases in a much higher ratio than is expressed by the weight of the charge in lbs.; the original smoothness of the surface is sooner broken through, and gutters formed; and these gutters once formed, there is more heat and pressure tending to wear them deeper. It has consequently become a great object to try and check the flow of gas. One obvious way is to vent the gun and ignite the charge on the under side, but there are some practical difficulties in the way of this plan, and experiments have for some time past been in progress with wads of different materials. Of these the best has proved to be a wad of *papier machè* made a close fit, and cut to enter the grooves. It weighs for a 9-in. gun about 2 lbs. The good effect of using it has been remarkably illustrated by comparing the condition of the bore of

9-in. gun, No. 329 which has fired 500 rounds of 43 lb. charges with wads; with that of 9-in. gun, No. 298 which fired 1043 rounds without wads, of these the last, 500 were all with the same charge of 43 lbs., and they were fired with a new vent made in what had previously been the under side of the gun. The under surface which had been scarcely perceptibly marked by the previous 543 rounds, now became the upper surface, and both guns started for this comparison on equal terms. The following notes shew their further progress :—

GUN, No. 298, without wads.	GUN, No. 329, with wads.
The present top of the bore, namely grooves 4, 5, and 6, was the original bottom of bore, and as bottom of bore has fired 156 battering rounds, charge 42 to 45 lbs., 387 ordinary rounds, charge 30 lbs. and under; total 543. There is scarcely any perceptible scoring over this portion of bore, but groove 2 (now the bottom) is considerably cut along both edges, and the lands between 1 and 2, and 2 and 3, are also considerably scored. The vent of 298, is 9·75″ from end of chamber, and in the other case only 1½.	
After 100 *rounds :—*	
Very decided scoring on grooves 4 and 5, and on the lands between 4 and 5, and 5 and 1. The condition of the bottom (formerly top) unaltered.	No scoring whatever.
After 200 *rounds :—*	
The scoring on grooves 4 and 5, and lands between them produced by 200 consecutive battering charges is very materially greater, full twice as great as the scoring on grooves 1, 2, and 3, and the lands between them, produced by the whole 543 rounds previously fired. Scoring on grooves 1, 2, and 3, and the lands between them, not perceptibly increased.	A perceptible roughness. Roughness a little increased, and beginning to assume a reticulated character.
After 300 *rounds :—*	
Scoring on grove 5 much increased, and also on the lands between 4 and 5, and 5 and 6, so great as almost to obscure groove 5, the guttering being in places as deep as the groove. The deep part of this scoring is along the groove, for about 12″, after which it is still perceptible, though slight, for about 5″ further. The impression on groove 2 (now the bottom) and the adjacent lands is very slightly increased.	The scoring does not extend, a decided roughness at the upper part of the bore.
After 400 *rounds :—*	
On groove 5 the roughness is extreme, some of the cavities being nearly 0·5″ deep, and the loading edge is quite obliterated, and there are gutters	The roughness not perceptibly increased.

in the land on that side as deep as those on the edge of the groove. The driving edge is better preserved, but there are gutters in lands between 5 and 6 fully 0·2″ in depth; the reticulated appearance and the transverse lines are very strongly marked.

The deep part of the guttering extends about 20″ along the groove, and is perceptible an inch or two further.

After 500 *rounds:—*

The driving edge of groove 5 is still tolerably good, the loading edge is quite obliterated for a distance of 13″, the deepest cavity occurs in the lands between 4 and 5, and is about 0·6″ in depth.

The wearing of groves 1, 2, and 3 (present bottom), is a little increased, particularly along the landing edge, but is still comparatively insignificant.

The wearing along the loading edge of groove 6 is about equivalent to that on groove 2 at the commencement. The scoring of the lands between 6 and 1 is decided, but of no great amount.

The roughness extends generally over the lands and edges of the grooves, but is scarcely perceptible at the bottom of the grooves; it does not exceed ·02 or ·03″ in depth; except along the driving edge of one of the grooves, where it is rather more decided.

The conclusion drawn by the O. S. Committee is that the durability of the guns which use heavy charges will be greatly increased by the employment of wads of the nature specified. They need not be used when firing shells with time fuzes, as shells are only fired with ordinary charges, the effect of which is comparatively small.

There is much less difference than would be expected between the character of the markings in a wrought-iron barrel and those in a tempered steel barrel, the former however have rather a greater tendency to follow the direction in which the iron is piled, that is to run circumferentially; but the reticulated character is common to both. In some instances the steel wears at a certain stage into an appearance of scales overlapping each other, with the singularity that the overlap is towards the muzzle, that is to say, the edge of each so called scale is from the direction of the current, not towards it. The whole effect is full of interest to metallurgists, and will hereafter, when examples are more numerous, be well worthy of attentive study.

25. Artillery arrangements made for the expedition to Egypt in 1801.* The following extracts from a MS. in the Royal Artillery Library, Woolwich, will no doubt be interesting at the present time when the Abyssinian expedition is in prospect, more especially as correspondents in the daily Press have recommended that no Artillery should accompany the expedition on account of the difficulties which are likely to be met with. Major-General Lawson's notes shew that no argument of this nature is valid, and that the Abyssinian expedition will not be the first instance in which Officers of the Royal Artillery have had occasion to exercise their ingenuity in overcoming obstacles.

"The expedition under the orders of Admiral Lord Keith, and General Sir Ralph Abercrombie, proceeded from the island of Malta on the 21st of December, 1800; arrived at Marmorice Bay, in Asia Minor, on the New Year's Day following, and

* By Brigadier-General Lawson, Commanding the Royal Artillery of the Expedition,

remained there waiting the co-operation of the Turks (being the time of their Ramasan) until the 20th of February. During this period every measure was taken the situation admitted of, to lessen the numerous difficulties expected to be met with in Egypt, such as a dangerous shore to land upon, a country destitute of wood, water, or roads; where, as the Commander-in-Chief informed the General Officers (assembled by order), nothing was to be looked for but a wild waste of desert, and obstacles, which the most unremitting exertions had only a chance of surmounting, independent of a formidable opposition from the French troops.

"Under these ideas, and the battering train (originally designed against Bellisle only) having joined the army, very indifferently provided indeed for such an arduous enterprise—no time could be lost. All the artificers were landed, and strong working parties sent into the woods to cut down timber for making additional spars, skids and various sized rollers, to form gangways for landing the heavy ordnance upon, assisting them over deep sandy beaches, and in crossing the canals, formed for conveying the rising waters of the Nile into the towns, and cultivated spots of the country.

"The general acknowledged difficulty of travelling wheeled carriages in Egypt, induced the trial of a number of contrivances, to lessen that inconvenience also, the first of which, and most obvious, were a kind of litters, termed "Horse Barrows."

"No wood growing in this country proper for such purposes rendered it necessary to dig saw pits, in order to cut the pine timber into long scantling,* something near the shape of a common hand barrow, preserving the grain as entire as possible. Two movable cross bars which are secured by two small bolts, keep these shafts at a proper interval to admit a horse at each end between them. Fig. 1 shews

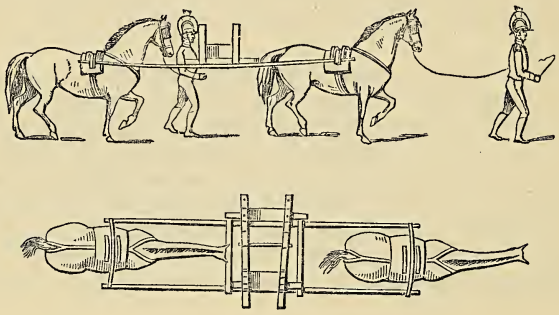

Fig. 1.

the manner of travelling the machine by two horses or mules, each having a small cart saddle with girth, back-band, breastplate, and crupper, and a halter for leading them by.

"These barrows were particularly useful for narrow paths and the trenches of an attack, or for conveying any individual weight too heavy for a single horse, such as a small piece of ordnance, standing carriage, large casks of provisions, &c.†

"Besides these single barrows, a design was formed for double ones consisting

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* Sixteen feet in length, and about four inches square.

† The powder and ammunition expended in the attack of Aboukir Castle was mostly conveyed from the landing place to the batteries in this manner.

of three shafts, as seen in Fig. 2, to be carried by four horses in pairs; and also others upon a still larger scale for camels, but neither time or materials admitted of their being put into immediate execution.

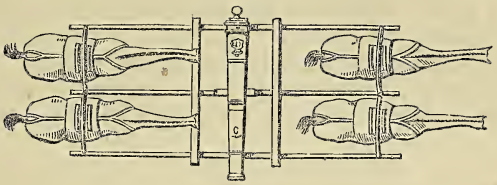

Fig. 2.

"A very considerable number of carrying poles about 9 ft. long each, were formed out of the small sized trees, to which rope slings were added, for the soldiers to convey kegs of musket ball cartridges, ammunition boxes, or royal mortars with, as represented by Fig. 3.

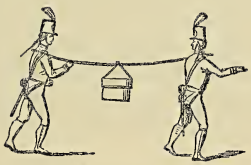

Fig. 3.

"A number of horses were purchased at Constantinople on the part of the English Government, and sent to Marmorice for remounting the light dragoons; and those rejected by them, were turned over to the artillery service.* Such poor undersized animals as they were, rendered it absolutely necessary, not only to take the harness entirely to pieces in order to bring it anything near fitting them, but also to lay aside all the heavy parts, such as neck collars, chain traces, curb bits, &c.; and replace them with light leather breast collars, rope traces, and pads formed out of the wagon harness, a great part of which, fortunately, was not likely to be otherwise called for.

"About 130 horses being thus completed with harness, some light pieces (guns and howitzers) were landed and a small park formed, in order to drill them to the draught. Every reform possible was made to lighten the travelling of the ordnance; and it was very much wished to have exchanged the limber shafts for poles also, on account of their weight, as well as other considerations, but no proper wood could then be procured even at the island of Rhodes for the purpose. The block trailed light 6-pr. carriages had ten horses allotted to each for draught, but the framed ones, required twelve, when going over heavy sand or shingle.

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* "The turning over only rejected horses from the dragoons to the artillery service, was not so well judged as might be expected. It would have been fortunate (the best of theirs bearing no comparison with the French cavalry) to have rendered the movement of the ordnance more effectual; as it was, both corps remained insufficient; the effects of which, were fully experienced in the action of the 13th March, when, had only a part of the number of pieces then in the field been very well horsed, the fate of Alexandria it is more than probable, might have been decided on that day. The French on the other hand, constantly applied the very prime of their strong horses (those belonging to the officers not excepted) to the draught of their ordnance, which were chiefly on the horse artillery establishment with 8-pr. guns (equal to British 9-prs., and howitzers as four to three in proportion) and 6-inch howitzers opposed to light 6-prs. and royals only."

"Planks joined together lengthways by staples and cordage, may be necessary, to travel the carriages upon over the heavy sands. The French, it is said, made use of raw hides, in passing the deserts with their field pieces; perhaps lengths of rope, about 30 ft. each with narrow netting between to receive the wheels upon, might be found as useful; and in our situation more readily procured.

"The moving of heavy ordnance over the deserts of Egypt, the French thought impracticable, and attempted no larger calibre than 8 or 12-prs. Something more however seemed necessary for us to make trial of against an enemy so much more formidable than they had had to contend with, independent of the ambition of superior resource.

"Upon comparing all circumstances together it appeared likely that, whatever works they might have raised in the interior of the country since their possession of it, could not be very solid ones, even if composed of masonry, for want of time to settle and the cement to harden sufficiently in such substances; and earth alone in this climate, must soon crumble to dust or sand, and easily be destroyed by shells. From these considerations it was concluded, carronades might probably be found sufficiently powerful to breach them in either case, at moderate distances, and be easily conveyed by the double horse or camel barrow across the country if necessary. The circumstance being suggested to General Sir Ralph Abercrombie, and at the same time the means proposed of altering the carriages for this purpose, without affecting their sea service in the smallest degree. His excellency communicated the idea to Lord Keith, who immediately ordered several of these 24-pr. carriages (though larger ones were wished for) ashore from the ships of war, to undergo the necessary alteration.

"The ammunition for field service was usually conveyed on camels' backs, each carrying four of the altered 6-pr. packing boxes,* two on each side, in a sort of netted bag thrown over a pack saddle; but useful as these animals are generally for great weights, there are inconveniences attending them in this particular service: viz. when loaded (which of course must be daily repeated) they move very slowly, therefore quite unfit for horse artillery. In order to load or unload, they must first be made to kneel down, which is an action they are not always inclined to, and sometimes become very refractory and unmanageable; whatever quantity of ammunition is required for the gun must always be taken equally from both sides at the same time, to preserve its equilibrium, &c.

"These reasons determined a trial of light carriages in their stead; first beginning with royal howitzer ammunition, it being the most dangerous and liable to injury. Some of the handcarts were selected for this purpose, and in order to travel the better, converted to curricles. The poles were accordingly lengthened, and cross bars fixed to support them in front by the horses collars, much in the same manner as the 3-pr. carriages formerly used in the horse artillery, only more simplified in other particulars. These carriages were drawn by four horses each, and went through all the marches of the army to and from Grand Cairo remarkably well, travelling very rapidly with forty-eight rounds of the howitzer ammunition, completed for immediate service, as already mentioned.

"Our cavalry from their want of proper horses, being found very unequal to the capitally mounted French dragoons, it became necessary to aid that defect by the attachment of artillery. Four light 3-prs. (brought from Malta) were first prepared for this service, their original mode of travelling with shafts and single line of draught was altered to a double one, by cutting off the shafts of the limber at the cross bar and introducing a pole instead of them; together with other improve-

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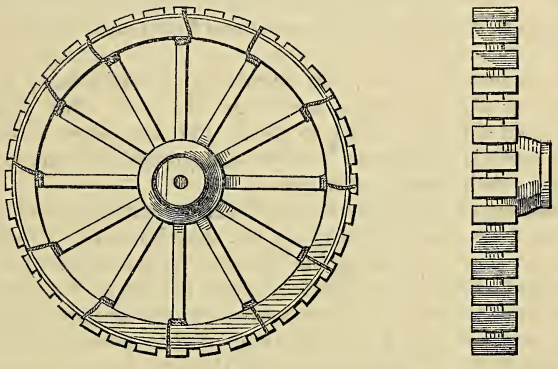
* Sixty rounds complete, and four extra case shot over.

ments.* Four or six horses with two drivers (according to the ground) drew the carriage. These pieces were served by four artillerymen, two on the carriage and two mounted on the off draught horses; they went through the service to Grand Cairo, and travelled much better than was expected from the lowness of the limber wheels, which defect there was no remedy for in Egypt.

"Four light 6-prs. upon block trailed carriages† with two royal howitzers were also equipped (as nearly as the means would admit) for horse artillery service. Seven artillerymen and three drivers with ten horses were allotted for the service of each piece, the gunners riding the horses in draught, but the N.C. officer mounted single, for the purpose of advancing to examine roads, reconnoitring the enemy, &c.

"It being apprehended that extraordinary weights might cause the low narrow wheels of the trench cart to sink so much into the sand, as to retard the draught considerably, a contrivance‡ was thought of to prevent this from happening, by occasionally increasing the breadth of the felloes. The staves of casks being strong, and of a favourable shape for this purpose (and still more valuable from their being easily procured at the Commissary-General's store) it was proposed to cut them into lengths, of seven or nine inches each piece, having two small iron staples fixed at an interval, the breadth of the felloe. A rope equal in length to the circumference of the wheel, is run through each of these lines of staples, secured so as not to slip out, but keep the staves parallel at one inch and a half asunder. They are then applied to the wheels as shewn by Fig. 4, and fixed by small lashings to the spokes, to keep the whole from any alteration in travelling."

Fig. 4.



* "A block of wood was fixed by two bolts to the back of the axletree, and the iron pintail removed from the centre of it to this block, to receive the trail of the carriage upon. This was done in order to make room for a 6-pr. ammunition box (containing 32 rounds complete for the gun), to be fixed crossways in the front; the old side boxes belonging to the carriage being rejected entirely, their places furnished seats for two gunners. A small expense ammunition box (containing 8 rounds), was made to fit in between the cheeks of the gun carriage after the French manner. A copper tray or drawer was introduced under one of the gunner's seats to contain the slowmatch, instead of carrying a linstock."

† "These carriages from their lightness, short draught and quick turning, passed over the inundation dikes, and desert with great ease, while the framed carriages with more horses were attended with difficulty and delay, and once in the desert obliged to be left behind."

‡ "If the mode mentioned of preventing narrow wheels from sinking in deep sandy situations, should have the appearance of possessing more fancy than judgment, it must be placed to the variety of obstacles which hourly presented themselves in Egypt, and called for every assistance the mind could catch at to surmount, and still perhaps, the idea may lead to something useful even in a northern climate, passing over snow, &c."

The following are a few of the "observations" which are inserted at the end of the MS.:—

"All the field ordnance which had been landed at Ferrol with Lieut.-General Sir James Pulteney's army, and afterwards joined General Sir Ralph Abercrombie, were re-embarked there in so disorderly a manner, no one piece was found fit for immediate service. This circumstance will for ever unfortunately occur, unless the direction of the business be left entirely to the artillery corps, whether navy boats and ships of war, or those of the ordnance only receive them.

"The disembarking of ordnance, unless in the instance of field pieces let down into the boats ready mounted from ships of war, however regularly performed, is always liable to some confusion. This principally arises from the parts of the same natures of carriages not corresponding so correctly as they might do, particularly in the diameters of the wheels and arms of the axletrees, which should likewise be as general, throughout the whole, as possible.* The wagons and carts being frequently made by contract, are very defective in these points, even to the fitting of their head and tail boards, and trifling as this may appear to a workman at home, often occasions delays of consequence to the service, or credit of those concerned in it abroad. No nation, in point of economy alone, requires so much attention to the construction and solid stowage of its military carriages and stores as Great Britain does, on account of their frequent embarkations, the expenses of which in the course of a war are prodigiously great.

"The oxen drew very well upon common ground, but in deep sand generally became restive. The large sized mules were excellent in draught when well disposed, but from their natural obstinacy, it was found best to intermix them with horses.

"Foreigners frequently observe the singularity of shafts being preferred in the British artillery carriages to poles, made use of by all other nations, as being simpler, lighter, and cheaper; added to which, the experience of having travelled over the most difficult features of Europe, and ground of every description with them, fully evinces their perfect sufficiency.

"A strong instance of the inconvenience of shafts occurred to us at Rahmanieh—just as one of the 6-prs. was limbering up, the shaft horse was killed by the enemy—much time was lost in clearing the carriage from him, and the trail harness being also damaged, rendered it difficult to apply another in his place.

"Flat boats are the best and most useful conveyance for troops and ordnance possible; every means therefore should be employed to preserve them from injury; though apparently slight, it is surprising what they can bear. In moving the stores up Lake Etcho, for the attack of Fort Julian, some of them were dragged three miles over sand and mud banks.

"The battering pieces for this service were obliged to be landed on the open sea beach, and conveyed four miles across the desert and swamps to their batteries.

"These laborious and difficult operations were frequently repeated during the expedition. Upwards of thirty 24-prs. were disembarked from the ordnance ships, conveyed by boats up Aboukir Lake, and landed near the head of it, for the attack of Alexandria,† from thence twenty were returned to the ships in Aboukir Bay, conveyed to the mouth of the western branch of the Nile, disembarked and taken

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* "The arms of the axletrees and diameters of the wheels of all carriages immediately connected with each other on service should correspond exactly; that is, the gun and limber, ammunition wagon and large carriages perfectly alike in their particulars."

† Seven 24-prs. were employed against Aboukir castle previous to this operation.

over that dangerous bar by sea jerms, landed at Fort St Julians, re-embarked there in river jerms, in order to proceed up the Nile. Several of them were landed within four miles of Grand Cairo, and conveyed from thence twelve miles across the country, for the attack of Gizeh. Returned back after the surrender of Cairo by the same route, and exactly in like manner to Alexandria; re-landed there for further operations of attacks, carrying on both on the eastern and western side of it, the capitulation of which, concluding the campaign, they were again conveyed to the ships in Aboukir Bay.

"Besides the articles already detailed, numerous minute circumstances happened in the course of the campaign which necessity continually urged the imagination to provide against. Every movement by land or water was attended with infinite labour and difficulties; added to which, the violent heat of the sun, and shocks received by passing over the formidable cracks it occasioned in the ground (annually overflowed by the Nile) on the march to Cairo, operated so powerfully on the carriages as to require perpetual attention and daily repair, without the most common materials for such occasions, either of wood or iron, to be found in the country."

The following is given as "return of ordnance captured in Egypt," viz.:—

In the field, March 8th, 5 pieces; 13th, 3; 21st, 2; Aug. 22nd, 7. Garrisons, Aboukir Castle, 11; Ft. Julian, 15; Ft. Burlos, 5; Grand Cairo and Dependencies, 121; Gizeh Lines and Arsenal, 530; Alexandria do, 411; Island of Marabout, 10; Damietta and walls of Lesbie, &c., 54; Ships of war in the harbour of Alexandria, 77. Total, 1251.

N.B. Besides the above, the French were allowed to embark fifty field pieces from Cairo, and ten from Alexandria.

26. VELOCITIES OF PROJECTILES AND METHOD OF CALCULATING REMAINING VELOCITIES. The following abstract shews the mean initial velocities of projectiles fired from various service rifled guns, with present description of powder (rifle L. G.).

Nature of Gun.	Calibre.	Charge.	Projectile.			Initial velocity.
			Nature.	Mean weight.	Mean diameter.	
	in.	lbs.		lbs.	in.	ft.
13-in. M.L. of 23 tons	13·05	70	Palliser	620	12·95	1220
" "	"	60	Common shell	620	12.97	1136
" "	"	50	"	"	"	1000
9-in. M.L. of 12 tons	9	43	Palliser	250	8·90	1340
" "	"	30	Common shell	250	8·92	1220
8-in. M.L. of 9 tons	8	30	Palliser	180	7·90	1330
" "	"	20	Common shell	180	7·92	1165
7-in. M.L. of 7 tons	7	22	Palliser	115	6·90	1465
" "	"	14	Common shell	115	6·92	1260
7-in. M.L. of 6½ tons	7	22	Palliser	115	6·90	1430
" "	"	14	Common shell	115	6·92	1230
64-pr. M.L. of 64 cwt.	6·3	8	"	64	6·22	1170
7-in. B.L. of 82 cwt.	7	10	"	110	7·09	1013
" "	"	11	"	90	7·09	1165
64-pr. B.L. of 61 cwt.	6·4	8·5	"	64	6·48	1160
40-pr. B.L. of 35 cwt.	4·75	5	"	41	4·8	1180
20-pr. B.L. of 16 cwt. (L. service)	3·75	2·5	"	21	3·8	1150
do of 13 cwt. (S. service)	"	"	"	"	"	1000
12-pr. B.L. of 8 cwt.	3·0	1·5	Segment shell	11·75	3·07	1170
9-pr. B.L. of 6 cwt.	"	1·125	"	9	"	1030

In calculating the loss of velocity due to the resistance of the air, the following approximate formula will be found to give very close results, when the velocities are as high as those given in the above table, and the range is moderate, viz :—

$$v = \frac{V}{1 + cVx}$$

where v = required velocity in feet,
V = initial velocity in feet,
x = range in feet,

$$c = 0{\cdot}000062\frac{R^2}{W},$$

R = semi-diameter of shot in ft.,
W = weight of projectile in lbs.

Thus, determine the remaining velocity of a Palliser projectile fired from the 9-in. rifled M.L. gun, with a charge of 43 lbs., the initial velocity being 1340 ft., and range 1000 yds. Here

$V = 1340$ feet,
$x = 3000$ feet,
$R = 4{\cdot}45$ inches or $0{\cdot}375$ ft.,
$W = 250$ lbs.,

$$c = 0{\cdot}000062 \times \frac{0{\cdot}375^2}{250}$$

$$= 0{\cdot}000000034875;$$

$$\therefore v = \frac{1340}{1 + 0{\cdot}000000034875 \times 1340 \times 3000}$$

$$= \frac{1340}{1{\cdot}140}$$

$$= 1175{\cdot}2 \text{ feet.}$$

In comparing the action of projectiles on striking an iron defence, such, for example, as an iron-clad ship, it is usual to estimate the effect by the stored-up "work" or "energy" in the shot at the moment of impact.

This is equal to the weight of the shot in lbs. multiplied by the square of its velocity in feet, and divided by twice the force of gravity. The result being a number of foot pounds, which, for convenience, are turned into foot tons, as a less number of figures are required to express the latter. Thus,

$$\text{Total foot tons} = \frac{Wv^2}{2g \times 2240},$$

where W = weight of shot in lbs.,
v = velocity of shot on impact in feet,
g = force of gravity = 32·19 feet,
2240 = number of pounds in a ton.

This equation gives the total "energy" in the shot.

When, however, it is required to compare two projectiles as far as their *power of penetration* is concerned, it is usual to express the stored-up "energy" in terms of their diameter or circumference. Thus a shot is said to have so many foot tons of "energy" per inch of its circumference—its total "energy" must therefore be divided by the number of inches in its circumference, and the last equation will become

Foot tons per inch of shot's circumference

$$= \frac{Wv^2}{2g \times 2240 \times 2\pi R}$$

where $\pi = 3{\cdot}1416$,
R = semi-diameter of shot *in inches*.

Thus, determine the total "energy" and "energy" per inch of circumference of a Palliser projectile fired with a charge of 43 lbs. from the 9-in. rifled M.L. gun; range 1000 yds.

Here we have already found

$$v = 1175{\cdot}2 \text{ feet},$$

so total "energy" $= \frac{250 \times 1175{\cdot}2^2}{64{\cdot}38 \times 2240}$

$$= 2394 \text{ foot tons};$$

and "energy" per inch of shot's circumference

$$= \frac{2394}{2 \times 3{\cdot}1416 \times 4{\cdot}45}$$

$$= 85{\cdot}63 \text{ foot tons.}$$

N.

27. ROCKET DETACHMENTS, NORTH COAST OF SPAIN, FOR MOUNTAIN SERVICE, 1836–40.*

Two natures only were employed, 6 and 3-prs., the first were chiefly, and the second wholly, shell rockets.

The 6-pr. subdivisions consisted of,—

2 n.c. officers ..... } Carrying 2 rocket tubes of 6 feet, made to screw
14 gunners ..... { together when necessary, and form a tube 12 ft.
2 Spanish muleteers { long; and 140 rockets. The subdivision was
8 mules ..... } capable of acting when needful in two sections.
5 mules carried each 28 rockets } 140 rockets.
2 mules " " 70 sticks }

The 8th mule carried the tents, provisions, and forage. The loads were,—

		lbs.	lbs.	
Of Nos. 1 and 5 mules called the "Front Mules."	The rocket tube	19	198	†
	18 shell and 10 shot rockets	149		
	The magazines	30		
Of Nos. 6 and 7 mules	70 rocket sticks	159	173	
	A pair of stick buckets	14		

The loads of Nos. 2, 3, and 4 mules were less by 19 lbs. (weight of rocket tube) than those of 1 and 5, but they were each fitted to carry it.

Nos. 3 of each section of the detachment carried a linstock and portfire, and Nos. 1, 2, and 4 leaders of quickmatch for ground volleys, in cavalry cartouch boxes.

On preparing for action the four last Nos. of each section took out and carried amongst them, 12-rocket sticks, and also gave 2 to No. 4 who fixed them to rockets and carried them ready, one in each hand:—one mule only, thus needed to be brought under fire at a time.

The 3-pr. subdivisions consisted of,—

2 n.c. officers .....
6 gunners ..... } Carrying 2 hand rocket guns, and 224 rockets,
1 Spanish muleteer { capable of acting in 2 sections.
5 mules .....

Four mules carried each 56 rockets and sticks, making 224 rockets.

The 5th mule carried a tent, provisions, and forage.

Nos. 1 and 3 mules carried each a hand rocket gun; and the saddles of 2 and 4 were also fitted to carry them, when required to relieve 1 and 3.

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* The information here given is from Memoranda by the late Colonel Colquhoun, R.A.

† 43 lbs., the weight of the pack saddle, must be added to these weights.—Ed.

The loads of the 3-pr. mules were,—

		lbs.	lbs.
Of Nos. 1 and 3 called the "Front Mules."	The rocket gun and leather cover ...	20	276 *
	56 shell rockets for 550 and 750 yards, in equal numbers	157	
	56 rocket sticks	58	
	The magazines	30	
	The quivers for rocket sticks.....	11	
Of Nos. 2 and 4 mules (less by weight of gun 20 lbs.)			256 *

The n.c. officer and one man of each section carried leather tube pouches, each containing 75 percussion priming tubes.

6-pr. Horse Artillery rocket subdivisions,—

At Vittoria, in 1835, a division of mounted rocketeers was formed in the horse artillery of the British Legion, to accompany the movements of cavalry.

The rockets were carried partly by the mounted men in holsters, or fixed, and the rest on led-horses in magazines upon a troop saddle, the flaps and pannels of which were made wide and thick to bear the pressure of the load. The led-horses were fully equipped, ready to be mounted when the magazines were removed, the reins and stirrups being made up so as to render them no incumbrance. The magazines contained 22 rockets, 2 more were carried in holsters, and 3 under the cantle in a small valise, making 27; but the horses carrying rockets could not carry sticks.

The subdivisions consisted of,—

9 n.c. officers and men.....
9 horses for do.....
3 other men with a led-horse each

} making 12 men and 15 horses. { carrying 2 cavalry rocket tubes of 6 ft., and 84 rockets; forming when needful 2 sections.

These led-horses and the men in charge of them, carrying 60 rockets, were called the *first reserve*, and there was a second set of 3 other led-horses with a mounted man in charge of each, carrying in precisely the same manner, 60 more rockets, called the *second reserve*, making,—

	Men.	Horses.	Rockets.
The detachment	9	9	24
The first reserve	3	6	60
The second reserve	3	6	60
And the subdivision to consist in all of ...	15	21	144

The detachments were told off from 1 to 9, and the reserves in continuation. Nos. 5 and 8 carried the rocket tubes and were horse-holders. No 2. was also a horse-holder. Their formation was as follows,—

6	5	4	2	1
9	8	7	3	

Nos. 6 and 9 carried portfires in front of the near side holsters, and slow matches in an iron tube attached to the near stirrup: all except the horse-holders carried in their cartouches, leaders for ground volleys.

* 43 lbs., the weight of the pack saddle, must be added to these weights.—Ed.

The rockets were carried as follows:—

	Rockets.
No 1. (serjeant) and 5 n.c. officers and men carried each 3 rockets and sticks, viz. 2 rockets in holsters, and 1 fixed in bucket on off side...	18
No. 2 (horse-holder) carried 2 rockets in holsters and 6 sticks in a bucket on off side	2
No. 5 and 8 (horse-holders and rocket tubes) carried each 2 rockets in holsters, but no sticks	4
Total with front detachment of 9 men	24

The 1st and 2nd reserves were precisely alike, the men leading the horses had neither rockets nor sticks. The two first led-horses of each reserve carried 22 rockets in magazines, 2 in holsters, 3 in a valise. The third led-horse carried 60 rocket sticks, or 2 bundles and 6 rockets in a valise between them, but nothing in holsters or on the cantle. 120

The led-horses were found capable of keeping pace with the detachment at the gallop, but the troop saddles proved ill-suited to the purpose they were applied to, and light pack saddles were substituted afterwards at St Sebastian, with advantage.

28. Endless band saw for cutting wrought-iron. The endless band saw for cutting *wood* is the invention of M. Perin, who exhibited it in the Paris Exhibition of 1855, where it was purchased by Colonel Tulloh, then Superintendent of the Royal Carriage Department.

For the purpose of cutting *iron* it is driven at a very slow speed, about 250 feet per minute being found the most suitable. The teeth of the saw are set straight and cut very fine, about ten to the inch, and it should be of the hardest kind of saw steel that can be obtained. Iron one inch thick can be cut in any curved form at the rate of $1\frac{1}{2}$ inches per minute.*

This saw is extensively used for cutting the brackets, transoms, and all irregular forms required in the manufacture of wrought-iron carriages; the advantage of this process consists in the saving of time, as the work requires very little finishing after it comes from the saw, and there is less waste of material.

29. The following Table contains a full description of the construction of the French Imperial vessels, of which models were exhibited in the Paris Exhibition.

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* Specimens of which may be seen in the Royal Carriage Department, Woolwich.

Marine Impériale.—Bâtiments

	Magenta, — Vaisseau cuirassé de 900 chevaux.	Flandre, — Frégate cuirassée de 1er rang de 900 chevaux.	Gloire,—Frégate cuirassée de 1er rang de 900 chevaux.	Marengo, — Frégate cuirassée de 1er rang de 950 chevaux.	Alma,—Corvette cuirassée de 450 chevaux.	Bélier, — Garde-côtes cuirassée de 530 chevaux.	Arrogante,—Batterie flottante de 120 chevaux.	Embuscade,—Batterie flottante de 120 chevaux.
Nature de la coque	Bois.	Bois.	Bois.	Bois et fer.	Bois et fer.	Bois carapacéen tôle.	Fer	Fer
Auteur du plan	Dupuy de Lôme.	Dupuy de Lôme.	Dupuy de Lôme.	Dupuy de Lôme.	Dupuy de Lôme.	Dupuy de Lôme.	Lemoine.	Lemoine.
Longr de la flottan en charge sans différence	m. 86,65	m. 80,00	m. 77,89	m. 87,75	m. 70,10	m. 66,00	m. 44,00	m. 39,50
Largeur au fort hors bordé ou hors cuirasse.....	17,28	17,00	17,00	17,40	14,00	16,05	14,60	15,80
Creux au milieu sur quille à la ligne droite des baux du 1er pont.....	8,30	8,48	8,16	10,57	fort central 6,98 en dehs du f. c. 6,28.	5,37	3,17	3,92
Tirant d'eau moyen en charge.....	7,77	7,84	7,83	8,00	5,96	5,40	2,65	2,85
Tirant d'eau arrière en charge.....	8,45	8,45	8,45	8,45	6,56	5,40	2,75	2,95
Déplacement en charge ...	6651t^x	5772t^x	5719t^x	7172t^x	3400t^x	3456t^x	1352t^x	1242t^x
Surface du M.C. (flottaison en charge)	107m^2	104m^2	101m^2	116m^2	67m^2	73m^2	38m^2	44m^2
Surface de voilure en voilure majeure	1711m^2	1960m^2	1660 m^2	2024m^2	1453m^2	"	237m^2	237m^2
Constructeur de la machine	Mazeline.		Cie de la Méditerranée.		Cie de l'Océan.			Creusot.
Système de machine	bielles renversées.	bielles renversées.	bielles renver.	bielles renversées.	bielles renversées.	2 machines à bielles renversées.	2 machines à bielles directes.	2 machines à bielles engrenages
Nombre de cylindres	2	2	2	3	3	3	1	1
Diamètre des cylindres.....	m. 2,10	m. 2,10	m. 2,08	m. 2,10	m. 1,60	Chacune. m. 1,20	Chacune. m. 0,86	Chacune. m. 0,86
Course du piston	1,30	1,30	1,27	1,30	0,85	0,70	0,75	0,75
Nombre de tours par minute	51,5	51,30	48,5	55	70	88	80	80
Système de propulseur...	hélice à 4 ailes en porte à faux.	hélice à 4 ailes en porte à faux.	hélice à 4 ailes.	hélice (présumée)	hélice (présumée)	2 hélices à 2 ailes simples (présumée)	2 hélices à 4 ailes.	2 hélices à 4 ailes.
Vitesse aux essais	n. 13,5	n. 14,34	n. 13,5	n. 14,5	n. 12,5	n. 12	n. 8	n. 8
Epaisseur de la cuirasse ...	0,12	0,15	0,12	0,20	0,15	0,22	0,12	0,14

dont les modèles sont exposés.

Décidée, — Canonnière de 1re classe de 50 chevaux.	Aspic. — Canonnière de 2e classe de 40 chevaux.	Chaloupe canonnière démontable de 12 chevaux pour l'expédition de Cochinchine.	Plongeur, — Bateau-porte torpilles.	Infernet,—Corvette rapide de 450 chevaux.	Jérôme Napoléon, — Corvette à barbette de 450 chevaux. (Yacht du Prince Napoléon).	Bouret,—Aviso de 2e classe de 160 chevaux.	d'Estrées, — Aviso de 1re classe de 250 chevaux.	Creuse, — Transport-écurie de 430 chevaux.	Cher,—Transport de 400 t^x et 150 chevaux.	Aigle, — Corvette de 500 chevaux. (Yacht Impérial).
Bois.	Bois.	Fer	Fer.	Bois.	Bois.	Bois.	Bois.	Bois.	Bois.	Bois.
Aurous.	Lemoine.	Dupuy de Lôme.	"	Bienaymé.	Normand.	Vésigné.	Pastoureau	Guesnet.	Huin.	Dupuy de Lôme.
m.	m.	m.	m.	m.	m.	m.	m.	m.		
37,64	39,20	24,90	42,50	78,60	78,10	54,98	63,21	82,00	63,78	82,00
6,72	6,44	4,90	5,96	10,90	10,62	8,44	10,36	13,40	13,30	10,50
2,81	2,658	2,10	"	6,62	5,84	4,49	5,40	10,63	6,40	4,85
2,35	2,10	1,42	"	4,80	4,57	3,30	4,20	6,07	4,49	4,40
2,60	2,20	1,50	"	5,40	5,29	3,85	4,85	6,60	4,80	4,50
363t^x	278t^x	89t^x	429t^x	1916,33t^x	1609t^x	679t^x	1208t^x	3581t^x	1674t^x	1908t^x
m^2			m^2							
12,60	9,97m^2	5,26m^2	12,67	39,59m^2	32m^2	17m^2	28m^2	62m^2	36m^2	33m^2
502m^2	370m^2	167,65m^2	"	1453m^2	1453m^2	1613,85m^2	"	1550m^2	1215m^2	901m^2
		Cie de la Méditerranée,	"	"	Mazeline.	Indret.	Indret.	Indret.	Indret.	Mazeline.
mach. à engre.	machine à engrenages	machine à haute pression.	"	bielles renversées.	bielles renversées.	bielles renversées.	bielles renversées.	bielles renversées.	bielles renversées.	Oscillante.
2	2	1	"	3	3	3	3	2	3	2
m.	m	m.		m.	m.	m.	m.	m.	m.	m.
0,68	0,56	0,35	"	1,28	1,42	1,10	1,25	1,65	1,10	1,82
0,65	0,60	0,300	"	0,80	0,80	0,50	0,70	0,95	0,50	1,90
58,89	80	200	"	90	83	85	"	61	75	24
hél. à 2 ailes doubl.	hélice à 4 ailes déployées.	hélice à 4 ailes.	hélice	hélice (présumée)	hélice à 4 ailes en porte à faux.	hélices à 2 ailes doubles.	hélice à 2 ailes doubles en porte à faux.	hélice à 2 ailes doubles en porte à faux.	hélice à 2 ailes doubles	Roues.
n.	n.	n.	n.	n.	n.	n.	n.	n.	n.	n.
8,64	8	7,5	6	15	14,21	12.00	11,5	12,15	9	13,75
"	"	"	"	"	"	"	"	"	"	"

30. Bashforth's Chronograph. When a body moves in a straight line under the action of a force in the direction of its motion, which varies as the (velocity)^3, a well known simple formula gives a relation between the velocities V and v at two points of the path of the body s feet apart. Professor Hélie uses $v = \frac{V}{1 + cVs}$, I use $v = \frac{V}{1 + 2bVs}$, so that the $2b$ of one is the c of the other. The constants $2b$, or c, depend upon the *form* of the moving body, but they of necessity vary inversely as its weight. For *similar forms* of heads of projectiles it is usual to *assume* that the resistance varies directly as the section or as the (radius)^2, In this case b, or c, will vary as the (radius)^2. On this supposition I shall be able to apply results obtained from the 12-pr. B.L. gun and 40-pr. M.L. gun to other calibres.

In the trial experiment with my Chronograph with 12 lb. service shot, it was found that $2b = \cdot000\ 000\ 084$. (Report dated Dec. 18, 1865), and in the description of the Chronograph the value was more exactly given,

$$b = \cdot000\ 000\ 0417.*$$

Taking the shot at 12 lbs. and the radius $= 1\frac{1}{2}$ in. $= \cdot125$ ft. we get,

$$2b = c = 2 \times \cdot000\ 000\ 0417 \times \left(\frac{R}{\cdot125}\right)^2 \times \frac{12}{W}$$

$$= \cdot000\ 064 \frac{R^2}{W},$$

adapted for a shot of *similar form*, of radius R feet, and weight W lbs.

Again, in Sept. 1866, some experiments were made with shot having heads of different forms, (1) hemispherical, (2) hemispheroidal, the diameters being nearly in the ratio 1 to 2, (3) ogival struck with a radius of one diameter, and (4) ogival struck with a radius of two diameters. In the report (Oct. 23, 1866), numerical values were given for bl^2, as stated below, where $l = 150$ feet, the distance between the screens. These values have been employed to adapt the results of these experiments to shot of *similar forms* but of different diameters and weights.

Gun.	Form of head.	Weight of shot.	Number of rounds.	Value of bl^2.	Value of $2b$ *or* c.	Date.
		lbs.				
12-pr. B.L...	Service	12·00	11	.....	$\cdot000\ 064 \frac{R^2}{W}$	Dec. 1865.
40-pr. M.L.	½ Sphere.	39·33	5	·000 840	$\cdot000\ 077 \frac{R^2}{W}$	Oct. 1866.
.....	½ Spheroid, ...	38·69	4	·000 669	$\cdot000\ 060 \frac{R^2}{W}$	"
.....	Ogival (1 diam.)	21·81	10	·001 245	$\cdot000\ 063 \frac{R^2}{W}$	"
.....	Ogival (2 diam.)	21·94	8	·001 181	$\cdot000\ 060 \frac{R^2}{W}$	"

* See "Proceedings," R.A. Institution, Vol. V. p. 186.

31. PELLET POWDER. "Pellet powder" has been provisionally approved for charges of guns over 12 tons weight.

The powder, in place of being made into press cake and then granulated, which involves the formation of a quantity of smaller grains and particles, is pressed into cylindrical pellets about ·5″ long ·75″ diameter, perforated at one end to about the centre.

The object is to obtain a comparatively slow burning powder having a large and uniform grain or pellet.

32. RESISTANCE OF IRON ARMOUR PLATES. An experiment was carried out at Shoeburyness, on 29th July, 1867, for the purpose of ascertaining the resistance of wrought-iron plates backed by iron, or built up armour plates, in comparison with solid plates.

The targets were supplied by Messrs Cammell of Sheffield, for this experiment, and consisted as follows:—

No. 1. Two $3\frac{1}{2}$-in. plates riveted together, making a total thickness of 7 in. The plate being 5 ft. × 4 ft.

No. 2. Three $2\frac{1}{3}$-in. plates riveted together, making a total thickness of 7 in. The plate being 5 ft. × 4 ft.

The iron of which these plates were composed was identical with that used in No. 7 solid plate.

Both targets were firmly secured to wooden supports, but unbacked.

They were fired at with Palliser shot from the 7-in. rifled M.L. gun of 7 tons. Range 70 yards.

The following conclusions may be drawn from these results, taken in conjunction with those of previous experiments:—

(1) With the above gun and projectile at this distance, it would require about 15·5 lbs. of powder to perforate a *solid* 7-in. plate. The "energy" in the shot being about 61 foot tons per inch of its circumference.

(2) It requires about 14 lbs. of powder to perforate a 7-in. compound plate made up of two separate thicknesses of $3\frac{1}{2}$-in. riveted together, the "energy" in the shot being about 57 foot tons per inch of its circumference.

(3) It requires about 13 lbs. of powder to perforate a 7-in. compound plate made up of three separate thicknesses of $2\frac{1}{3}$-in., the "energy" in the shot being about 52 foot tons per inch of its circumference.

These results shew that plates thus built up in *thick* layers bolted together, afford a very large amount of resistance, although they are not quite equal to a solid plate.

It is probable that the resistance of three 5-in. plates riveted together, would more than equal that of a solid 13-in. plate, while they would be decidedly cheaper.

By calculation, it would require 16·94 foot tons per inch of shot's circumference to perforate a $3\frac{1}{2}$ inch plate; and 7·53 foot tons to perforate a $2\frac{1}{3}$ inch plate, provided the plates were taken individually.

33. PROPORTIONAL MILITARY MODELS.*—These are blocks of boxwood chiefly rectangular, representing companies of infantry, squadrons of cavalry, guns,

* Designed by Capt. W. A. Ross, R.A., and can be obtained at R.A. Institution, Woolwich.

wagons, horses, &c., *made in proportion to the real size* (except of course vertically), according to the most convenient scales *which are engraved on the inside of the lid* of each box. Thus the scale on which a box of light field battery models is constructed, is of course very much larger than that appropriated to the illustration of movements of a brigade of the three arms combined. The boxes of all kinds are 18×2 inches, and as shallow as possible, so that the lids serve,—besides purposes of mensuration applied to the table on which the models are placed and to themselves in column or line, &c.,—to wheel up or back, or dress lines or columns, which they will be found to do on a moderately smooth table, with great facility and correctness.

The models for the illustration of drills appertaining to any one of the three branches of the army, being on a large scale, can be applied to that purpose alone, while on the other hand, it is submitted that the brigade models, constructed on a scale of one inch to 20 yards, may fairly aspire to the solution of stragetical or tactical problems, and enable two operators provided with boxes at either end of a large table, to carry out a series of manœuvres, as outflanking, deploying, &c. against each other, and it is also hoped that they will serve for the illustration of particular campaigns, better and more correctly than military maps.

A detailed printed description accompanies each box.

34. RESISTANCE OF THE AIR TO THE MOTION OF PROJECTILES. Some interesting experiments have lately been carried out on the resistance of the air by Capt. W. H. Noble, R.A., under the direction of the O.S. Committee, using the 12-pr. B.L. rifled gun and 9-inch M.L. rifled gun, advantage being taken of other trials to observe a second velocity with each round.

The trials were made with two of Navez-Leur's electro-ballistic machines, which had previously been found to work so closely together, that the probable error was reduced to less than one foot.

The results appear to shew that:—

(1) The resistance of the air is practically proportional to the square of the diameter of the projectile.

(2) Within the limits of 1500 and 1100 feet, the resistance appears to vary nearly as the velocity cubed, and employing M. Hélie's formula, given in p. 26,*

$$v = \frac{V}{1 + c\sqrt{x}},$$ c will nearly equal $0{\cdot}000063 \frac{R^2}{W}$ within those limits.

(3) When the velocity of the projectile passes below 1100 feet, there appears to be a gradual, but at the same time, rapid reduction in the amount of resistance, as if the projectile were being rapidly relieved from some extra pressure, this rapid diminution ceases when the projectile reaches about 1000 feet, and

(4) Within the limits of 1000 and 600 feet, the resistance appears to vary nearly as the cube of the velocity, and employing the formula

$$v = \frac{V}{1 + c\sqrt{x}},$$ c will nearly equal $0{\cdot}000034 \frac{R^2}{W}$ within those limits.

(5) It is difficult to account for the rapid diminution of resistance between 1100 and 1000 feet. It may be that after the projectile passes below 1100 feet velocity, the front part is relieved from extra pressure by permitting the air to run in behind, and so fill up the partial vacuum in rear of the shot,

R = radius of shot, W = weight of shot.

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* See Traité de Balistique expérimentale par Hélie, Professeur à l'Ecole d'Artillerie de la Marine: Paris, 1865.

SHORT NOTES ON PROFESSIONAL SUBJECTS,

1868.

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35. Shipwreck of the Transport "Phillis," 1795.

The following letter, addressed to the Adjutant, 4th Battalion, by Lieut. Howard Douglas, R.A. (afterwards General Sir Howard Douglas), describes with singular simplicity, the famous shipwreck of the transport *Phillis* with a detachment of the Royal Artillery in 1795. The tale has been often told,—and among other places will be found in that excellent little work "England's Artillerymen," by Serjeant J. A. Brown, R.A. Band, with particulars to his honor, from other sources, which the modesty of young Douglas omitted in writing his own account: it will however bear repetition, and in the present authentic form acquires a fresh interest. He was in his nineteenth year at the time. The Committee are indebted for the original to the Rev. Sir Thomas Blomefield, Bt.

Great Jarvis in the Island of Newfoundland,
2nd Dec. 1795.

Dear Sir,

A small vessel which sails by the first wind for England, gives me the opportunity of sending you (for the information of General Patisson) the following melancholy account, of the detachment of the Royal Artillery, which embarked for Quebec, on board the ship Phillis in August last.

On Sunday the 11th of October, which made exactly the ninth week of our voyage, we had only got as far as the Island of St Petus (about forty leagues to y^e^ eastward of the southern entrance of the Gulph of St Laurence), during which nine weeks, we suffered every hardship, which could arrive from bad weather, and a scarcity of fresh provisions. It is necessary to mention that on the Thursday which preceeded, in a very severe gale of wind, a heavy sea broke both our boats from their lashings upon deck; a circumstance which greatly contributed to our future misfortunes, as in securing them again, we were obliged to lash them with their bottoms upwards, the cheeks having been lost.

On the night of Sunday the 11th a gale of wind sprung up from the eastward which continued till four o'clock on the afternoon of Monday the 12th, when in an instant it fell quite calm. Between six and seven in the evening the chief mate of the ship came into the cabin, and called out the captain in a very mysterious manner, and soon after some of us going upon deck, heard very plainly the noise of *Breakers*, that noise increasing every instant, we were soon convinced we had got into a strong current, which set us towards the shore, and that we were inevitably lost unless a breeze sprung up from that quarter.

Our cables being unbent all hands were turned up to bend them; which being done, we let go our best bower anchor in about twenty-five fathom water; the land beginning to appear on all sides of us—we soon perceived our anchor did not hold, and as the last resource, set to work to get out the boats, which on account of their

being turned upside down, was a very difficult piece of work. This however, we might easily have accomplished, had the ship's company behaved like men, but as soon as they knew their danger, they left their tackles, and stood like cowards, waiting their fate, which they had not courage enough to endeavour to avoid. In hort at about half-past eleven that night, we struck with astonishing violence on a ock, about a quarter of a mile from the main land. That horrible scene baffles all description; nor I am sure can even the most lively imagination convey half its horrors. After shaking very violently two or three times, the ship drifted again towards the shore; where she settled upon a rock just as she was sinking. In this situation, we turned our thoughts once more towards the boats, but could get nobody to work at them, except the captain, two mates, the carpenter, Lieut. Caddy, and myself. And with great difficulty we got the small boat over the side, when Lieuts. Caddy, Forbes, and myself got into her, to prevent her from staving against the ship's side. But in spite of all our efforts, she was soon nearly half full of water, so that we were obliged to leave her again. In getting back to the ship I missed my hold, and fell down between the ship and the boat, I swam a few strokes to the boat, and was taken in by Forbes, who with Caddy and myself, soon after got safe on board again. The boat we left, was soon in pieces; and the long boat, which was still hanging in the tackles, was also soon demolished. Being now in momentary expectation of the ship's parting, those who could swim, stript themselves, to be in readiness to make that last struggle for their lives. Thus we stood, during the remainder of that long, long, night; wet through with the continual dashing of the breakers; eagerly wishing for day, in hopes that as soon as it dawned, the inhabitants would see us, and come to our assistance. At length it came, but only served to augment our distress, by presenting to our view, a rough uncultivated mountainous country; without the least vestige of human being. We discovered that the rock on which the ship was now settled, was not above fifteen yards from a point of the main land which we have since heard is named little Boy Head (about three leagues to the eastward of Cone Boy in this island), which point of land terminated towards us in an almost perpendicular rock. And we feared the heavy sea occasioned by the preceeding day's wind, w^{d} render our landing in a manner impossible; by the violence with which it broke against y^{e} rocks. This we were soon convinced of, by the dismal fate of poor Barckley,* and one of the seamen, who altho' they were very expert swimmers, were unable to struggle long with the breakers. They left the ship, to try to swim on shore about nine o'clock, the seaman had just reached the shore, when a breaker with great violence, dashed him against the rocks, and we saw him no more. Poor Barckley (from what cause we know not) had only swam a few yards when he stopped, and after struggling a few moments in the agonies of death, and waving his hands to us upon deck, he sank for ever. The composure with which he bad us all farewell before he committed himself to the waves was affecting and admirable. In his efforts to gain the shore, he was stimulated as much from an idea of saving *our* lives, as his own, but what makes his behaviour still more wonderful is, that he did not leave the ship, till he had seen the seaman dashed against the rocks. Poor Barnes, soon followed him, for as he was standing by the fore chains, a wave swept him from thence into the deep, and as he could not swim, his sufferings were soon at an end. To relate separately the awful scenes of death which we now beheld, w^{d} only augment my distress, in recalling so exactly to my memory, that fatal day. Suffice it to say, that during that day, Mrs D'Estimanvile was swept by the waves from the arms of her husband, Chev^{r}. D'. a French emigrant passenger in the ship; Lieut. Barckley's

* This officer's name was Barclay. In this as in other instances which will be observed, the Editor has retained the misspelling of the original, which is characteristic of the period, and interesting from the great subsequent distinction of the writer.

servant was washed overboard, and a soldier's wife and two children shared also the same fate. Towards evening one of the sailors unfortunately got a cask of wine, with which many of them got intoxicated; it proved fatal to the cook of the ship, and Thomas Coats, Lieut. Caddy's servant. I am happy in being able to say that the rest of our men were perfectly sober. We remained the whole of this day being Tuesday the 13th and that night on the wreck, without anything to eat except a piece of pork and a cheese which we found floating on the deck. On the evening of Wednesday the 14th the weather was so moderate, and the sea so smooth that it appeared practicable to make a raft capable of taking two or three men on shore who as soon as they landed might come to our assistance. We accordingly set to work and made one, on which two seamen got in safety to the shore, but after waiting two hours, finding they neglected us, we made another longer one, with which the second mate, carpenter, and two seamen landed; who came immediately to assist us, in endeavouring to get on shore. By their means we got a rope from the end of the bowsprit to the shore, on which one by one, we all landed in safety about four o'clock that afternoon. To our infinite joy we found a great quantity of cloaths of all kinds had come on shore from the wreck, part of the ship's cargo, from which we each of us took a large cloke and then took up our lodging for the night, in a small thicket of spruce trees. Soon after dark it rained very fast, which soon pierced the slender shelter they afforded us; and made us completely uncomfortable. About twelve o'clock, my servant's wife (who had been very ill ever since we landed) went delirious, and raved during the whole of the night, in the most shocking manner, which prevented us taking that rest, of which we stood so much in need. Towards the morning of Thursday the 15th it cleared up; and soon after day, the sun shone with great power; certainly the greatest blessing the Almighty could send us; as by its influence, we were enabled to dry our *tinder* (which in spite of all our endeavours had got wet in bringing on shore) and kindle a fire: but we did not get it time enough, to be of service to those who most wanted it; for my servant's wife died about ten o'clock that morning, her death was certainly occasioned by the cold. Not having implements of any kind to dig a grave, we committed the body to the deep.

This morning we found Lieut. Truscot, and Benet, who were taken ill the preceeding night, so very bad, that we had no hopes of their recovery. The ship having been chiefly laden with pork, and butter, for King's stores at Quebec; great quantities of each of these articles were driven on shore; as also three casks of wine, which latter I know not whether to call a fortunate circumstance or not, as some of our men were often intoxicated, which generally ended with a quarrel. Having fried a few pieces of pork we all sat down and made a hearty meal, as you may suppose, after fasting nearly three days and nights. *After dinner* we all met, to consult upon the most eligible plan we could adopt, for our future safety—when in consideration of our not having tools of any kind to build a house, wherewith to shelter onrselves from the inclemency of the weather, in so rigorous a climate, nor provisions to last us long; it was unanimously determined, that after waiting where we were, for a few days, (to see if Messrs Truscot and Benet recovered so far as to be able to accompany us), we should each of us furnish ourselves with as much provision as we could conveniently travel with, and set out to endeavour to find an inhabited place. On the morning of Friday the 16th, we found Messrs T. & B. instead of recovering had got so much worse, that far from there being any probability of their being able to accompany us in our intended journey, there were scarcely any hopes of their living many days; and as our staying in that place, would be only sacrificing ourselves, without being able to be of the smallest service to them, (the frost having already seized on the feet of both of them) we determined (distressing as the idea was, to leave two of our companions behind in such a situation) to set off the next morning in search of inhabitants, or perish in the attempt.

Accordingly we assembled early on the morning of Saturday the 17th, each of us with a cloak and provisions, and began our march. About sun-rise this morning, Messrs T. & B. were in a state of insensibility; and in this state, in anguish of mind undiscribable, we left them, with a good fire, and provisions within their reach, fervently recommending them to the care of the Almighty Power.

In solemn silence we continued our day's journey over almost inaccessible mountains and thro' almost impenetrable woods; till about two o'clock, when we took up our quarters for the night, in a wood on the rise of a hill, well covered with wood, and plenty of water near us. After making a fire, we eat a small piece of pork, (which but served to sharpen our appetite), and then endeavoured to get some rest, and for a few hours smother our distresses in sleep. On Sunday the 18th, we proceeded on our journey, but soon found it impossible to penetrate any further into the country. We found ourselves in a valley, covered with impenetrable woods, skirted by inaccessible mountains, and frequently interspersed with impassable rivers; from which, it was impossible to get out, except by the way which we entered. This soon convinced us, of the impossibility of pursuing our journey; and determined us, to return to the unfortunate spot of our shipwreck, and there to build some kind of hut, to secure all the provisions we could, and there to wait our fate. This plan being universally agreed to, we measured back our steps to the place we had stopt at the night before; where we remained, while three of our party went on to the place where Messrs T. & B. were, to endeavor to afford them assistance if they still existed, & on Monday the 19th we returned also, and immediately set to work in saving our provisions. We were inexpressibly happy to find Messrs T. & B. alive, altho' their feet were severely frost bit. On Tuesday y^{e} 20th, a party of 4 men were sent out, to pick up what provisions could be seen floating about, whilst the rest were employ'd in planning and beginning a hut. We chose a situation for it, in a small thicket of spruce, where we cleared a space sufficient for our purpose, leaving such trees, as were in a right line, and w^{d} serve for the direction of its sides, and ends; after which, we got 4 strong planks, from the wreck, (the ship went to pieces the day after we landed), which we lashed to the trees we had left, at about 3½ feet from the ground, securing them well where the trees were not strong enough with stakes. This done, we built a wall of stone that end which was most exposed to the sea; on the outside of which, we put a thick coat of sod, which, to supply the want of spades, we dug with the staves of a cask sharpened at the end; for the other end, and sides, short planks from the ground against the top of the beam which were placed on the outside of which all round we built a thick wall of sods. The formation of its top was exactly after the formation of an English cottage, altho' a very humble imitation; after the rafters were placed, we laid planks over them, above which, we put a covering of sods, leaving a small hole in the centre of the top for the smoke. According to this plan, we all worked very hard till it was finished. I forgot to mention that on our return from our journey, our first employment, was to erect a *flag-staff* on the highest ground we could find; upon which we hoisted a black and white flag; in hopes it might be perceived by some small boat that might go along shore. To this, we owe our present existence, for on Saturday, the 31st of Oct., at about three o'clock in the afternoon, we were perceived by a small schooner, the master of which, saw our flag, and knowing the place to be uninhabited immediately concluded it was a signal of distress, from people who were cast away; and instantly made towards land, and took us on board; and on the 12th of November landed us in safety at this place, where we are comfortably lodged in the house of Mr Roone, son of Harris Roone, Esqr., of Dartmouth, having lossed Lieuts. Barckley & Barnes and John Grant & Thomas Coats, gunners. When I arrived here I found it impossible to get to Placentia or St John's (the season being so far advanced) which I had intended to have done had it been possible; accordingly have taken up my winter quarters with the detachment,

in this place; and shall take the first opportunity in the spring, of a vessel to Quebec. The day after our arrival here, Messrs T. & B. went to a place about 7 leagues from hence, to be under the care of a female surgeon; the only medical assistance to be got here; and we have just heard that they are recovering fast. Mr Bennet has losed all the toes of the left foot.

This place is the residence of a merchant, who has in store all kinds of necessaries to sell to the inhabitants hereabouts; and therefore the best situation we could be in; as both ourselves and the men were almost intirely destitute of cloaths of every kind. I have got the men (as you will see by the enclosed account) only what is absolutely necessary in so cold a climate as this, and with regard to their allowance of meat, have also been as economical as possible. Enclosed you have the separate acknowledgments of each man, for the receipt of the different articles charged to them.

We paid John Brine the Master of the schooner which conveyed us here 30 guineas, as a recompense for his going above 50 leagues out of his way, which on account of the lateness of the season, deprived him of his winter's work, for which I hope the Board will make us some allowance, if General Patisson will be good enough to make an application.

Signed,

Capt. Frazer,
Adjutant 4th Batt.
Royal Artillery.

HOWARD DOUGLASS,
1st Lieut. Royal Artillery.

36. Horse Transports.

The following information gives the experience of Major Probyn, Commanding 1st Seikh Irregular Cavalry, regarding the transports employed in conveying his regiment between India and China in 1860.

The Committee are indebted to Captain Heath, C.B., R.N. for communicating to them what is now published, and they hope hereafter to be enabled, through the kindness of Colonel Adye, C.B., to publish further information on the same subject, which was gained from the more extended experience during the Crimean campaign.

Precis of the contents of report :—

Horse ships should not have false decks unless they are properly caulked. Should have large scuppers to carry off the urine. Should have bow-ports if possible. Should have side-ports on each side. Great attention should be paid to the ventilations, if the voyage is to be in warm latitudes. The horses should be on the main deck. The stalls should be 7′ long and 2′ 6″ wide, from centre to centre of stanchions, a space of 3′ 6″ or 4′ in rear of the stalls to enable the men to clean the horses properly. To effect this it may be necessary to diminish the space between the row of stalls on the opposite side of the ship. The height between the planking of the decks should never be less than 7′. The iron pegs for fixing the side boards should be attached to the stanchions with a short chain, otherwise they are frequently lost. There should be a strong bamboo, 15″ below the upper one. Cross battens should be placed directly beneath the sideboards, made so as to allow the urine to run off. The feeding troughs should have strong fixings as they get rough handling. There should never be less than 10 per cent. of spare stalls on long voyages, 25 per cent. only of resting slings, 6 shipping slings in each ship—1 scraper per stall, 50 per cent. of brooms, with a reserve.

Coir mats are most useful, but should only be used in rough weather, as they are liable to stink, and become full of insects if not taken up.

Hay nets one per horse.

A horse requires six gallons of water per day in hot weather, in cool weather five.

Oats are superior to gram, the latter frequently causing gripes.

Chloride of zinc should be freely and frequently used.

The men's accommodation should not be bulk-headed off from the horses. It should be whitewashed once a week, and the horse deck every ten days.

The same paper contains the following information regarding Land Transport and Cattle Transports from Lieut. G. Allgood, who was Dep.-Asst.-Qr.-Mr.-Gen. to the 1st Division of the Expeditionary Forces in China in 1860:—

Land Transport.

Great waste of life occurred amongst our land transport animals in China. The manner in which they were shipped (those sent from Bombay excepted), and the wretched condition in which they remained until the end of the campaign in spite of the abundance of forage always available, may be attributed to the following causes:—

(1) The Military Train under whose immediate supervision the animals were placed, were unaccustomed to look after them, and ignorant of fitting and looking to their gear. The syces were composed of Indians, Manilla men, and others, and, with few exceptions, could neither understand, or be understood by the officers and men placed over them. The syces were wretched, and uncared for, and as a natural consequence the animals were neglected.

(2) The faulty pack saddles gave the animals sore backs, little attention appears to have been paid to fitting them. The only good pack saddle was the *pad pack saddle*, sent with the mules from Bombay. It can be injured with difficulty, seldom gives sore backs, and is easily repaired. No other should be used.

(3) The fittings of the ships which carried the ponies were often flimsy. The ponies were stowed away like sheep. In one vessel from Japan seventy-five ponies perished by the fittings having given way in a gale. To judge by the condition of the ponies brought from Manilla, Japan, &c. but little care can have been bestowed on them during the voyage.

(4) There appeared to be little or no system in the management of the transport animals.

Should an expedition be again sent to China, Persia, or Egypt, the land transport should all go from Bombay, and a special corps organized composed of efficient men.

The officer selected to command, as well as those under him, should be especially chosen on account of their activity, knowledge of the treatment of animals, and also of the vernacular. Their pay should be such as to secure the best men. Intelligent privates from Dragoon regiments, men with a good knowledge of the vernacular, and smart attentive men should be placed over the syces and drivers as non-commissioned officers, in the proportion of one non-commissioned officer to twenty syces. A similar number of intelligent natives, as jemadars, should assist the non-commissioned officers.

One syce should be embarked with every two mules or ponies.

The corps should be divided into divisions, subdivisions, &c. and a regular system of internal economy and control established. The non-commissioned officers should be armed with hunting whip and revolver only; and should be mounted on ponies.

The Commanding Officer should be alone responsible to, and under the orders of the principal Commissariat officer. The corps should be organized and in working order before it embarked. The non-commissioned officers and men should be practised in fitting saddles, loads, &c. picketing and other useful work.

Surplus saddles and all kinds of gear should be sent with the head quarters of the corps, and a staff of moochees, and blacksmiths, &c.

The ships should be strongly and carefully fitted, and the animals should be daily groomed, attention paid to their food and watering. Each animal should have a separate stall, otherwise in bad weather there will be much loss amongst them.

In China we used a light English built 4 wheeled wagon, and Maltese carts. In countries where the roads are tolerable they are, I think, preferable to pack animals, are more economical, and easily loaded.

Each wagon was drawn by four mules or ponies, and carried 1500 lbs. The harness should be of the simplest and the stoutest materials.

Cattle Transports.

The mortality amongst the slaughter cattle and sheep brought to Talien-whan, for the use of the army, was excessive. Often one-third of each ship load died on the voyage, and the remainder were so poor as to be unfit for use.

From enquiries I have learnt that both sheep and cattle on board ship require *special* care, in respect to their diet and watering. I would recommend when sheep and cattle are shipped by the Commissariat, that competent ship's butchers be placed on board to look after and attend to them, at whatever price the services of such men may be obtained.

37. Shrapnel Shell, *v.* Segment Shell.

The following information is extracted from Vol. V. Part 2 of the Reports and Proceedings of the O.S. Committee :—

The results of practice at Shoeburyness with shrapnel shell for rifled guns are most satisfactory, and afford conclusive evidence of the formidable nature of the shrapnel shell. It is apparently most effective when burst within 100 yards of the target, and at about 10 feet above the plane, but its efficiency in the larger natures is still retained even when the burst takes place at so great a distance as 300 yards short of the object, a condition which the Committee believe would not be realized by projectiles constructed on the segment principle.

A careful analysis of the results in reference to the practice with 7-in. breech-loading shrapnel and segment shell fired for direct comparison, and under conditions most favourable to each construction, shows that 3229 bullets and splinters of shells took effect, against 1102 segments and splinters of shell, the bullets however weighing only 1·2 oz. each, the segments 3·3 oz. each.

If lodges and indents be disregarded in each case, the number of 1·2 oz. bullets or splinters which actually passed through 2-in. deal targets, was 2558 from the 11 shrapnel shell, whereas the 11 segment shells furnished only 552 segments and splinters.

The Committee make the following recommendations :—

(1) The immediate introduction of shrapnel shell and Boxer's wood time fuzes, for all breech-loading guns.

(2) The suspension of the manufacture of segment shell for all calibres.

(3) The future withdrawal from the service of the E time fuze so soon as the issue of shrapnel shell is completed.

(4) That the fuze holes of common shells for field calibres be assimilated to that of the shrapnel, so as to adapt them to take the same time fuze.

38. Rainfall at Cherra Poonjee, Bengal.*

Lat. 25.12 N. Long. 92 E. Elev. 4460 ft.

To the Secretary R.A. Institution, Woolwich.

Sir,

As the rainfall at this station is perhaps greater than in any other part of the world, during any one year, I have procured the following information which may be of interest. The rainfall in May observed from the first burst of the rains about the 22nd, was 49 in., that for June 109 in. The estimated rainfall at the new station of Shillong distant 32 miles is only from 75 to 80 in. annually.

Cherra Poonjee is at the top of the first range of hills rising from the plains very abruptly to 4460 ft. The country for about 20 miles in a northerly direction continues to rise till the highest elevation in these hills is reached at 6450 ft. The rainfall beyond this range is comparatively small.

There was much rain in April and the latter part of March at intervals, which was however not noted.

C. WILSON,
Captain, R.A.

Sept. 25, 1867.

JULY, 1867.

Station.	Date and hour.	Thermometer Dry.	Thermometer Wet.	Wind.	Cloud. Sky covered=1.	Rain.	Remarks.
	9 a.m.	°	°			in.	
Cherra Poonjee.	1st	73	72	S.W.	1·		Fine morning, low drifting clouds.
	2nd	71	70	S.E.	1·	0·65	Calm.
	3rd	67	67	E.	1·	1·70	Mist and light drizzle.
	4th	67	67	S.W.	1·	2·30	Light rain and mist.
	5th	69	68	S.W.	·9	1·70	Showers and sun.
	6th	68	67	S.S.W.	1·	12·75	Heavy continuous rain.
	7th	70	69	S.S.W.	1·	7·00	Rain.
	8th	69	69	S.S.W.	1·	6·60	Rain, mist, and drizzle.
	9th	70	68	S.	·8	4·25	Clouds rising, not rainy.
	10th	68	68	S.W.	1·	6·00	Steady rain, breeze.
	11th	68	68	S.W.	1·	8·05	Heavy rain during night.
	12th	68	68		1·	10·40	" " "
	13th	69	68	S.W.	1·	7·20	" " " breeze.
	14th	71	70	S.	·8	4·60	Sun, rain stopped.
	15th	76	72	S.	·7	...	Sun, fine morning.
	16th	74	71	S.W.	·5	...	Slight showers at night, not measurable.
	17th	76	72	S.E.	·3	·10	Very fine morning.
	18th	72	70	E.S.E.	·9	·80	Fine morning. Clouds rising.
	19th	72	71	S.E.	1·	1·55	Drizzle, mist, and rain.
	20th	71	71	S.	1·	·70	Drizzle.
	21st	70	69	S.	1·	·50	Light drizzle.
	22nd	68	68	S.S.E.	1·	2·10	Steady rain.
	23rd	72	71	S.E.	1·	3·20	Drizzle, heavy rain at intervals.
	24th	70	69	S.W.	1·	3·40	Steady rain and mist.
	25th	70	70	S.W.	1·	3·10	" " "
	26th	72	72	S.E.	1·	2·70	" " "
	27th	72	72	S.	1·	5·20	" " " nearly calm.
	28th	70	69	S.	1·	4·00	" " " "
	29th	68	68	S.S.W.	1·	11·10	Heavy continuous rain.
	30th	68	68	S.E	1·	10·40	Continuous rain, mist.
	31st	68	68	W.S.W.	1·	8·70	" " and breeze.

Total rainfall for July=130·75 in.

* Observations taken at Cherra Poonjee, July and August, 1867. By Captain H. H. Godwin Austen, B.S.C., Topographical Survey.

AUGUST, 1867.

Station.	Date and hour.	Thermometer Dry.	Thermometer Wet.	Wind.	Cloud. Sky covered. = 1.	Rain.	Remarks.
	9 a.m.	°	°			in.	
Cherra Poonjee.	1st	69	69	S.E.	1·	1·9	Raining.
	2nd	71	70	S.E.	0·6	0·9	Fine morning, sunny.
	3rd	76	72	S.E.	0·3	1·65	" Thunder storm overnight.
	4th	70	69	...	1·	2·48	Rain from midnight till morning.
	5th	69	69	S.W.	1·	2·5	Rain and mist.
	6th	68	68	S.	1·	3·0	Drizzle.
	7th	69	69	S.	1·	2·1	"
	8th	70	70	S.E.	1·	5·0	" steady rain all night.
	9th	70	69	S.	1·	1·85	"
	10th	70	70	S.	1·	1·45	Rain from midnight; distant thunder.
	11th	71	70	E.S.E.	1·	0·07	Bright morning, clouding over.
	12th	71	...	E.S.E.	0·8	...	Very hazy all day.
	13th	73	70	S.E.	0·1	...	Breeze, fine; morning overcast.
	14th	68	67	S.	0·1	0·9	Rain from 10 p.m.
	15th	66	65	S.E.	1·	1·75	Rainy evening, mist.
	16th	67	66	S.S.W.	1·	2·5	Rain all night.
	17th	68	67	S.S.W.	1·	2·7	Raining.
	18th	71	70	...	0·9	0·9	Raining all night; clearing up.
	19th	70	68	...	1·	0·02	Fine in early morning.
	20th	69	69	S.E.	1·	2·2	Drizzling, rain, gleams of sun; light clear evening.
	21st	69	69	S.E.	0·9	1·75	Rain off and on all night; gleams of light.
	22nd	69	68	S.S.E.	0·9	0·85	Thin mist over plateau, with a drizzle occasionally.
	23rd	70	70	W.S.W.	1·	6·4	Very heavy rain and strong wind; lightning about 1 a.m.; wind and rain up till time of observation.
	24th	72	70	W.	0·9	1·7	Raining great part of night. Fine, clearing.
	25th	70	69	S.W.	1·	2·4	Rain since early morning.
	26th	70	69	S.S.E.	1·	3·1	Rain all night.
	27th	69	68	S.S.W.	1·	4·4	" "
	28th	73	70	S.W.	0·7	0·3	Fine morning.
	29th	75	73	S.S.E.	0·9	0·5	" Thunder and torm in night.
	30th	70	70	...	1·	0·2	Drizzle.
	31st	73	71	S.S.E.	0·8	1·45	Fine morning.

Total rainfall for August=56·92 in.

The rainfall for the present month up to date has been 34·4 in.

39. Retirement from the Non-Purchase Corps of Royal Artillery, Royal Engineers, and Royal Marines.

Although no decision has yet been come to regarding the future system of retirement in the non-purchase Corps, it will no doubt be interesting to those Officers who have not access to the Report of the Select Committee on Army (System of Retirement), to know the recommendations the Committee have submitted to the House of Commons. They are as follows:—

(*a*) That the present system of retirement, on annuities of £600 or £400 a year, or on permanent half-pay after 25 years' service, and the practice of purchasing commissions by means of the Army Reserve Fund, be discontinued.

(*b*) That at the age of 60 every Colonel of Artillery or Engineers be placed on a reserved list, and while on that list, be considered ineligible for ordinary regimental duties, but eligible for staff or special employments, if selected by the military authorities. That an officer so removed should receive the pay of a Major-General, and retain his right of succession to the Major-Generals' establishment and to the command of a battalion.

(*c*) That every colonel, on removal to the reserved list, should have the option of retiring from the army on £600 a year, with a step in honorary rank.

(*d*) That every officer, after completing 22 years' service, should have the absolute right to retire, with a step of honorary rank, and with an annuity according to the following scale, irrespective of pensions for wounds or distinguished service :—

Number of years' service.	Annuity.	Probable age.	Probable value of annuity.
	£.		£.
22	250	42	3270
	increasing by £25 annually to		
25	325	45	4080
28	400	48	4780
30	450	50	5050
	increasing by £15 annually to		
35	525	55	5400
40	600	60	5510

(*e*) That provision be made by Parliament to enable an Officer to compound (through the agency of the National Debt Office) his annuity for its "present value," regard being had to his age and the state of his health, and the computation of value being made at 5 per cent. interest.

(The fourth column in the above table shows the values of the proposed annuities on the assumption that the life is good, and that the officer obtained his commission at 20 years of age).

(*f*) That no commutation of pension be allowed except on the retirement of the officer.

(*g*) That no officer be retired on half-pay except for wounds or ill-health, and that officers rendered unfit for service by ill-health, be allowed to continue on the half-pay list, whatever their length of service may have been, power being retained to bring them back to their former place in the corps when pronounced fit for duty.

The Committee would refer to the evidence given by His Royal Highness the Field Marshal Commanding in Chief, with respect to officers placed on temporary half-pay.

(*h*) That it should be in the discretion of the military authorities to employ or not any officer who shall have acquired the right to retire on a pension.

(*i*) That retirement from the Marines should be governed by similar regulations, the maximum annuity being £600, except in the case of an existing Colonel Commandant, whose annuity may be £700 a year.

It will be necessary, in future arrangements with the Government of India, to provide for the due proportion of the cost of the retirements of Artillery and Engineer Officers being defrayed from Indian revenues.

40. Norton's American Tube Well.*

This well consists of a hollow wrought-iron tube, the lower end of which, being provided with an eight-square point, and perforated with a number of small holes, is driven by means of a monkey or weight into the ground.

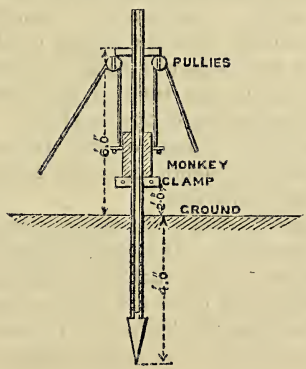
The lower length is 11 ft. long over all, of which the solid point is 10 in. long, and, being welded 2 in. into the lower end of the tube, leaves the hollow part of the tube 10 ft. long. The holes extend up the tube in six parallel rows $1\frac{1}{2}$ in. apart, for a length of $2\frac{1}{2}$ ft., their total area being about $1\frac{1}{2}$ times that of the internal diameter of the tube, which is $1\frac{1}{4}$ in., while its exterior diameter is $1\frac{13}{16}$ in.

The weight per foot is about $2\frac{3}{4}$ lbs. The tubes sent down from London were in various lengths from 3 ft. to 9 ft., and, having a screw thread cut in each end, can be jointed together by means of iron collars 2 in. long, screwed over the ends, the joints being made good by means of white lead.

Driving the Well.

The position for the well being selected, a hole is made with a crowbar, perfectly vertical, in which the tube is inserted. A clamp of cast-iron, faced on the top and inside with steel, having a groove in the centre of the size of the exterior diameter of the gas pipe, with a screw thread cut roughly inside so as to lay hold of the pipe made in two pieces capable of being tightened up by means of two screw bolts, is placed on the tube at a height of from 18 in. to 2 ft. from the ground, according as the soil is difficult or easy, and screwed on firmly, care being taken to tighten each bolt equally.

The monkey, consisting of a hollow iron casting weighing about 75 lbs., with a couple of lugs, projecting one on either side, is next placed on the pipe, and lastly a couple of pulleys are clamped to the tube as high from the level of the ground as a man can conveniently reach, usually about six feet, a rope being rove through each pulley, and secured to the lugs on the monkey, Fig. 1. The monkey is raised by two men, who should work steadily together, and pull the ropes at the



Section of Well. Fig. 1.

same angle with the pipe, so as not to cause a tendency in it to lean over on one side more than on the other. The monkey may be steadied and assisted in its

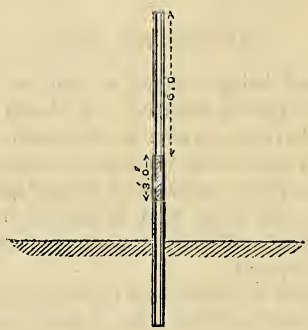
* Report by Lieut. W. B. Hurst, R.E., on Norton's American Tube Well.

descent by a third man, who, standing on one side, forces it down at each descent. On the clamp reaching the level of the ground, the monkey is raised while the clamp is unscrewed, and raised a height of 18 in. or 2 ft. up the tube, and again screwed up. The monkey is then lowered on to the clamp, and the pulleys are fastened higher up the tube.

The tube during its descent should be occasionally turned round in the ground, so that the position of the angles of the edges of the point may continually be altered. The same man who does this should pay particular attention to the clamp, to see that it does not move on the tube, tightening up the bolts at the first appearance of any slipping.

When the tube is driven so far into the ground that its upper end is not sufficiently high to carry the pulleys, a piece of pipe about 6 ft. long (Fig. 2), having a

Fig. 2.



piece of tube 3 ft. long, of the same exterior diameter (1¼ in.) as its internal diameter, brazed for a length of 18 in. into one end, and consequently projecting a length of 18 in., is placed in the upper end of the tube, and the pulleys clamped into it at a convenient height. The driving is continued until the first tube is driven all but two or three inches, when the clamp, monkey, &c. are removed, and an additional length screwed in by means of a collar. This length is driven as before, care being taken to turn round the tube in the boring to tighten up the joints, which become loosened by the jarring of the monkey.

Before screwing in an additional length of pipe, the well is sounded by means of a small lead line, to ascertain the depth of water or character of rubbish which penetrates through the holes in driving.

As soon as it appears that the well is driven deep enough, a pump is screwed in at the top, and the water drawn up. It usually happens that the water is at first turbid, but after a short time, as the chamber at the bottom of the well becomes enlarged, this turbidity ceases, and the water becomes pure.

When sinking in gravel or clay, the bottom of the well frequently becomes filled up, and it is necessary to remove the obstruction before a pure supply of water can be obtained.

To do this a pipe of small diameter is lowered down the well (the pump being attached to its upper extremity) to within about 1 in. of the solid material (as ascertained by the lead).

Water is then poured down the outer tube, and pumped up the inner one, gradually washing away the surface of the material until the well is cleared out to the bottom, as ascertained by the length of the inner tube, which can then be removed and the pump screwed on to the well.

The pipes when sunk can be drawn at pleasure in two or three ways.

(1) The monkey is placed on the head of the pipe, and the clamp screwed on, near the top. By raising the monkey, and striking the clamp a series of blows, the pipe is started and gradually drawn, the position of the clamp being shifted as required. Fig. 3.

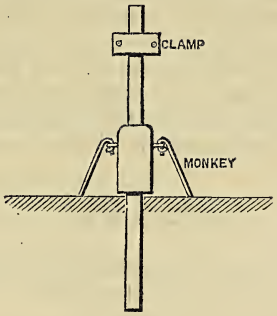


Fig. 3.

(2) A chain is passed once or twice round the pipe, one end passing through a ring at the other. A moveable link is then placed on the chain, and a lever or handspike inserted into the link, which tightening the chain round the pipe gradually lifts the well, the position of the chain being altered as required. Fig. 4.

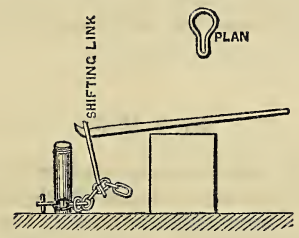


Fig. 4.

Stores Required.

The following stores are required for sinking a well in addition to pipes, pump, &c.:—

1 File.
4 Gas tongs, pairs ($1\frac{1}{2}''$, $1\frac{1}{4}''$, $\frac{3}{4}''$, $\frac{1}{1\,2}''$).
1 Crowbar 5 ft.
1 Spanner (for clamp).
1 Wrench (for clamp of pulleys).
1 Chain, 3 ft. and link.
*1 Monkey.
*1 Clamp.
*1 Pair of pulleys and clamp.
1 Tool (6 ft. gas pipe with piece welded in).
Gas pipe $1\frac{1}{4}$ in., weighs about $2\frac{3}{4}$ lbs. per foot.

	lbs.
Estimated weight of stores	142
Weight of pump	24
Weight of tubing for 20 ft. well	56

* The stores marked thus can be carried on the tool (the whole weighing about 100 lbs.) by two men.

Men Required.

Five men are required for driving a well quickly, allowing two men in two reliefs for working the monkey, while the fifth (a non-commissioned officer) steadies the monkey in its descent, attends to the clamp, and moves it and the pulleys as required. Three men could drive a well very well, although requiring more time, as the labour of working the monkey is rather severe, unless reliefs are provided.

Two wells were sunk at Chatham on the 22nd of September, and one at Wouldham on the following day, each by a different party of men, who consequently knew nothing previously of the process; Mr Norton's agent, Mr Hawkesley, and two American gentlemen being present on all three occasions.

No. 1 *Well.*

The first well was driven in soil consisting of clay, gravel, and large stones.

First pipe, 11 ft. long, was driven in 30 minutes.

The second length, 9 ft. long, in 39 minutes.

Water was now tried for and found, but not in sufficient quantities.

An additional length of pipe 6 ft. long was then attached, and the driving continued, several hard strata being passed through until a depth of 24 ft. from the surface was reached; for the next foot, the driving was easier; and at 25 ft. a copious supply of water was found, at first very thick, containing gravel and clay, but afterwards becoming whiter, leaving a slight deposit of chalk. If the pumping had been continued, the well would probably have cleared up. The point of the lower tube on being drawn was found uninjured.

No. 2 *Well.*

This was sunk in solid chalk without accident a depth of 17 ft. in 1 hour 25 minutes. No water was obtained at that depth, and as it was then dark the pipes were drawn, the point being slightly turned, but to so small an extent that after being filed up for five minutes it was again used for No. 3 well.

No. 3 *Well.*

This well was sunk at Wouldham three miles from Rochester, in the valley of the Medway. The well was commenced and the apparatus working within ten minutes of arriving on the ground.

The first 4 ft. was driven in a few minutes through a fine loam, the next 7 ft. required 47 minutes to drive, and after this, the strata becoming much harder, the progress was slower, as, one of the screws of the clamp pulley having broken, time was lost in procuring one to replace it.

A total depth of 18 ft. was attained in two hours, and 4 ft. of water found in the well on plumbing it. Driving was then continued, and at 22 ft. from the surface 8 ft. 6 in. of water was found in the pipe. On the pump being applied, the water came up with difficulty, and was thick and discoloured. In half an hour the quantity increased, and the water became purer. After pumping three hours, but a small quantity of chalk was brought up in solution, and the water was drinkable. The supply was at the rate of 10 gallons per minute, and, instead of diminishing, appeared to increase. This well was left in the ground.

41. Experiments at Shoeburyness. On February 20, 1868, practice was carried on from a 9-in. M.L. rifled 12-ton gun, mounted on a wrought-iron carriage, casemate slide (1867), at a moving target, to ascertain how many rounds could be fired at a vessel moving at right angles across the line of fire, at a range of 1000 yards.

The racers allowed traversing of the gun so that the vessel was under fire for a distance of 750 yards.

The detachment consisted of thirteen men under Lieut. Ellis, R.A., who laid the gun.

The size of the moving target, 5 ft. square.

The first round of each of the two series, was fired as soon as the moving target came into the line of extreme traversing.

First Series :—

	′	″	
1st round	0	0	
2nd "	1	17	Target moving at the rate of 3½ miles an hour.
3rd "	1	17*	
4th "	1	8	
5th "	1	10	
Total ...	4	52	Time occupied in firing 5 rounds.

Second Series :—

	′	″	
1st round	0	0	
2nd "	1	2	Target moving at the rate of 7 to 8 miles per hour.
3rd "	0	45	
4th "	0	45*	
5th "	0	50	
Total ...	3	22	Time occupied in firing 5 rounds.

In the first series, the gun was laid a-head of the moving target, and was not fired till the target had come up into line.
In the second series the gun was laid almost on the target.
Every shot would have hit a gun boat or even a man-of-war launch.
The traversing of the gun was done by tackles, one treble 8-in. block.
The gun charge, 30 lbs.; weight of plugged shell, 250 lbs.

42. Practice Carried on at Shoeburyness, from a 12-in. 23 ton M.L, rifled gun, mounted on wrought-iron carriage and platform placed on a turntable. firing through a port representing a portion of an iron fort.

Gun charge: 60 lbs.

Projectile: plugged common shell, 600 lbs. weight.

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* Hit target.

From the time of load for first round :—

		′	″
Load		0	00
1st round fired in		1	40
2nd	"	1	36
3rd	"	1	25
4th	"	1	33
5th	"	1	25
	Total	7	39

Average time—1′ 30″ each round.

Gun carefully laid on target, each time, at 1000 yards range.

Detachment—1 officer, 1 non-commissioned officer, and 17 men.

Operation of loading, by means of the cheeks of a 16 ft. gyn rigged as sheers.

Turntable traversed round each time under temporary sheers, in order for the shot to be lifted up to be placed in the bore.

43. Purchase of Mules for the Abyssinian Expedition.—The Committee of the R.A. Institution feel sure that every Member of the Institution will read with satisfaction the following complimentary letter from the War Office, conveying the thanks of the Secretary of State for War to Captain F. T. Whinyates, R.A. :—

Commandant's Office,
17/4/68.

The Major-General Commanding has great pleasure in publishing to the district the enclosed letter from the War Office.

By order,

(Signed) R. J. HAY, B.M.

No. 7678.
Alexandria.

War Office,
30th March, 1868.

Sir,

With reference to the letter from this office dated 24th ultimo, conveying the expression of Secretary Sir John Pakington's satisfaction at the manner in which the duties connected with the collection of mules for the Abyssinian expedition had been conducted by the military officers employed; I am now requested to state for the information of H.R.H. the Field Marshal Commanding in Chief that the Reports received from Egypt shew that the mules procured at Alicante were not only cheaper than any purchased in Spain, but also that they were of superior quality, which circumstance coupled with the fact that the shipments at Alicante were much larger than from any other port, induces Sir John Pakington to request that his thanks may be specially conveyed to Captain Whinyates, R.A., the military officer in charge, to whose intelligence and energy these satisfactory results are chiefly due.

I have, &c.,
(Signed) EDWARD LUGARD.

The Military Secretary,
Horse Guards.

Forwarded to Major-General Warde, C.B., for notification to Captain Whinyates.

(Signed) W. A. MIDDLETON,
A.A.G.

Horse Guards,
16th April, 1868.

44. Specimen of Slate-Coloured Partridge.—In Part XX. of Gould's *Birds of Asia*, published in April, 1868, a specimen of *Malacoturnix Superciliosus* is figured. This information will no doubt interest Members of the R.A. Institution, as the British Museum is indebted to Lieut.-Col. L'Estrange, R.A., for this valuable addition to the National Collection. Mr Gould thus refers to Lieut.-Col. L'Estrange's specimen :—

"It gives me great pleasure to figure, in the *Birds of Asia*, both sexes of this highly curious member of the *Gallinaceæ*—a bird which is, I believe, only known by two specimens in the Derby Museum at Liverpool, and an example in the British Museum, to which establishment it was presented by Col. L'Estrange.

When the bird was figured in the first part of the late Earl of Derby's 'Knowsley Menagerie,' its native country was unknown; and from that date, 1846, no other example had been recorded until Mr Blyth exhibited Col. L'Estrange's specimen at the Meeting of the Zoological Society on the 8th May, 1867.

"'Of this fine species,' says Mr Blyth, 'heretofore only known from a pair, male and female, in the Derby Museum, at Liverpool, which were said to have been brought from India, two examples were shot from a flock passing overhead in the vicinity of Massooree in unusually cold weather, one of which was given to Col. L'Estrange, of the Royal Artillery, who kindly submitted the specimen to my inspection. At the present time so fine a species is quite an unexpected addition to the list of Indian game-birds.'"

45. Resistance of Air. The results of some late experiments carried out by Capt. W. H. Noble, R.A., under the direction of the O.S. Committee, in which the velocity of spherical projectiles was observed at two distances, have shewn that the resistance of the air to these projectiles varies very nearly as the cube of the velocity, as adopted by the French School, and that the following simple formula may be used in determining remaining velocities of all projectiles, viz.—

$$v = \frac{V}{1 + cVx}$$

where

v = remaining velocity in feet,
x = horizontal distance in feet,
V = initial velocity in feet,
$c = b\frac{R^2}{W}$,
R = radius of shot in feet.
W = weight of shot in lbs.
b = 0·000081 for spherical projectiles,
b = 0·000063 for elongated projectiles of the usual service forms.

46. Calculation of Ranges. The following formula has been employed for the calculation of ranges of either spherical or elongated projectiles, viz.—

$$X = \frac{1}{2AV^2}\left(\sqrt{1 + 2AV^2\,\frac{2V^2 \sin 2\phi}{g}} - \cos\phi\right)$$

in which

X = horizontal range in feet,
V = initial velocity in feet,
g = force of gravity (32·1908),
ϕ = angle of elevation,
$A = z\frac{c}{V}$,

in which

V = initial velocity,
z = coefficient depending on the velocity,
$c = b\frac{R^2}{W}$,
b = coefficient depending on the form of the projectile,
R = radius of projectile in feet,
W = weight of projectile in lbs.

For most elongated service forms, the value of b will be practically constant and will equal 0·00181.

For spherical projectiles it has been found advisable and convenient to double this, so that the value of b will be 0·00362.

or $b = 0{\cdot}00181$ for elongated projectiles,

$b = 0{\cdot}00362$ for spherical projectiles.

With regard to z for elongated projectiles,

$z = 0{\cdot}025$ from the highest velocity to 1200 feet,

$z = 0{\cdot}020$ after 1200 feet.

With spherical projectiles this value of z is approximately as follows,—

$V = 1900$ to 1700, $z = 0{\cdot}024$.

$V = 1700$ to 1600, $z = 0{\cdot}022$.

$V = 1600$ to 1400, $z = 0{\cdot}020$.

$V = 1400$ to 1000, $s = 0{\cdot}018$.

47. On the Defects of Side-Arms for Muzzle-Loading Guns. Lieut. Greenfield, R.A., has forwarded the following remarks on this subject :—

The Sponge.

Till within the last ten or twelve months it was believed that the present service sponge was a tolerably efficient instrument for cleaning out guns after firing; but the evidence collected by a Board of Staff Officers (of which Col. L. Gardiner, Asst.-Adjt.-Gen., R.A., was President) 27/7/67, relative to three accidents that occurred in July last at Gosport, Portsmouth, and Dover, and which proceedings were laid before the O.S. Committee, together with the result of experiments conducted under their orders (Report No. 4851, 31/12/67), have proved the following facts, viz—that in firing blank ammunition a portion or portions of the cartridge remain in the bore after each round; and that the action of sponging out, only presses them home to the breech and there leaves them.

In consequence of this discovery, two changes have been approved, first in the service of the gun, the second in the material of the cartridge case. With regard to the latter, the Committee have been led by experiment to adopt a substance from the French—Amiantine cloth, a fabric made of refuse silk, which as its name denotes, does not smoulder or burn, but which yet remains in the gun undestroyed, in tolerably large quantities, sufficient to cause two miss-fires in fifty rounds. The same is well known to occur with serge cartridge, and its liability to smoulder depends upon its preparation.

That it is unadvisable to leave cartridge in the bore for a single round (especially the serge cartridge now in use all over the world) even though there be no sparks, is of course evident, as otherwise much fouling and many miss-fires would ensue. But the sponge is allowed to be unequal to this duty, as well as to the equally important one of searching well the grooving of rifled guns.

The wadhook.

I would suggest that the wadhook also is equally unfit. Indeed, throughout the service a strong opinion obtains that the wadhook is quite inadequate to remove the remains of cartridge in guns, and will not from its form and use seize hold of anything that is lying flat, as a piece of serge or silk, or that has not some substance, and offers a good deal of resistance, like a junk-wad or a cartridge; but for any thin substance lying along the bore it can hardly be considered an efficient instrument in the hands of our present gunners. If this seem a bold assertion, I would present the following as a proof: I have taken squads, amounting in all to 150 men, to different guns, and having in their presence put into the bore a piece of serge about the size of the palm of the hand, made each man search the gun for it with the wadhook in the usual manner; of the 150, only four men have brought it out on the point of the worm; *scraping* along the bore I did not permit, for that was not searching, and could have been done equally well with the other end of the stave.

There is also presumptive evidence to prove that this failure of the wadhook is acknowledged or feared, from the fact that the half-round scraper had to be used in experiments with Amiantine cloth and serge prepared with borax (Min. 3604, 18/11/67), to bring out large quantities and pieces of cartridge.

I beg to suggest also that it was this inefficiency of the wadhook to show that there was anything in a gun, that has more than once originated the idea that half-burnt cartridge adhered so firmly to the bore that it could not be detached.

To obviate these well-known defects in the service sponge and wadhook, I have endeavoured to produce an instrument of such a make, that it shall, if once sent home to the bottom of the bore, take away any foreign substance out of the gun under any conditions whatever, and thus by one action do the duty of sponge and searcher.

Turk's head brush.

The principle I have sought to attain, is to enter the bore low-gauge, and withdraw high-gauge, so as to get behind the piece of serge, or of seizing it, if at the bottom of the chamber or breech, and to bring it out, lighted or not, clear of the muzzle of the gun.

By this method I calculate upon keeping the gun clean and free from all substance that may catch fire at the next round, or foul the gun and cause miss-fire.

This idea I have brought to work in a brush, made of coir (or bass) let into a drum of wood similar to that of the present sponge-head. The bristles are at once set backwards and round the drum, so that they have a lay, all in one direction, downwards to the left. The effect of these two arrangements is, that in putting the brush into the bore, it moves home very easily, being compressible, but when home, half a turn to the left sets up the bristles, which being very stiff, seize hold of any substance adhering however closely, and the act of withdrawing still more sets them erect, till they scrape the whole periphery of the bore, a gentle turn of the stave maintaining the bristles set up, the whole time, and keeping in their grip

any substance once held. Hence it may be described as brush made of innumerable springs of coir.

I have chosen coir or bass as fulfilling best the conditions required; believing it to be the cheapest, the stiffest, and if well made the most durable kind of bristle that would do for the work. It does not easily burn, will not rust; and greasing or constant wetting is by no means detrimental to it, as the bass is fastened in by marine glue, and to wet it prevents it from breaking while in use without taking away their pliancy or rendering it soft. According to the length of the bristle, it will be stiff and searching or pliant; also it can be made as cheaply as the sweeps in the navy, and rather more so than the present service sponge.

In the hinder part of the brush-head the wood is turned smaller in diameter, and the bristles are longer than in the front half, so as to enable the latter to sweep well into the deep grooving of rifled guns.

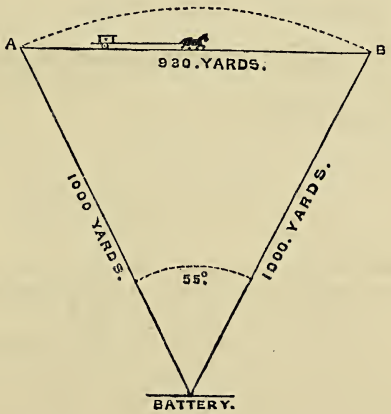
I have hopes, from the successful trials already made with it, that a brush-head of this make may solve the difficulty in sponging-out rifled ordnance, the great desideratum being a material that will search lands and grooves alike, and yet not be too high-gauge for easy service. It is intended for use as universal as the present sponge and searchers for all guns of similar calibre.

48. Practice Carried on at Shoeburyness, on May 15, 1868, from the undermentioned guns at a moving target, 5 feet square.

The extreme traversing of the gun from right to left 55°.

Distance of target from battery at extreme traversing, 1000 yards.

AB, distance passed over by target, 930 yards.



(1) 9-inch M.L. rifled 12-ton gun, mounted on a wrought-iron carriage and platform, and firing through a port.

Gun charge: 30 lbs.

Projectile: common shell, 250 lbs. weight.

Detachment: 1 officer, 1 non-commissioned officer, and 13 men.

Traversing done by tackle and iron shod levers.

First Series :—

	′	″	
1st round	0	0	Target moving at a walk.
2nd "	1	23½	
3rd "	0	56	
4th "	0	50	
5th "	0	58	
6th "	0	58½	
Total ...	5	6	Time occupied in firing 6 rounds.

Second Series :—

	′	″	
1st round	0	0	Target moving at a trot.
2nd "	0	50½	
3rd "	0	44	
4th "	0	50½	
5th "	1	2½	
Total ...	3	27½	Time occupied in firing 5 rounds.

(2) 12-inch M.L. rifled 23-ton gun, mounted on a wrought-iron carriage and platform, on a turntable, and firing through a port.

Gun charge : 50 lbs.

Projectile : common shell, 600 lbs. weight.

Detachment : 1 officer, 1 non-commissioned officer, and 20 men.

Traversing done by tackle.

First Series :—

	′	″	
1st round	0	0	Target moving at a walk.
2nd "	2	28½	
3rd "	2	20	
Total ...	4	48½	Time occupied in firing 3 rounds.

Second Series :—

	′	″	
1st round	0	0	Struck target 1 ft. from bull's eye.
2nd "	2	16	Target moving at a trot.
3rd "	2	3	
Total	4	19	Time occupied in firing 3 rounds.

49. Iron Plate Experiments. Experiments have recently been made at Shoeburyness to test the power of resistance, to Palliser shot, of unbacked iron plates, 10 inches in thickness, in comparison with that of two 5-inch plates bolted together.

For these experiments a 9-inch M.L.R. gun of 12 tons was used, at 70 yards range.

One 10-inch plate was manufactured by Messrs Cammell, of the Cyclops Iron and Steel Works, Sheffield; the other by Sir John Brown & Co., of the Atlas Works, Sheffield, being a sample of those intended for the "Monarch."

Messrs Cammell's plate successfully resisted the penetration of two Palliser shot of 248 lbs. weight, each, fired with a 43 lbs. charge, but the official report states that "the first round (which was fired with a 25 lbs. charge), caused the 10-inch plate to separate into two 5-inch plates, and the rest of the experiment was practically at a compound structure of two 5-inch plates."

The "Atlas" plate was first tested at Portsmouth with nine cast-iron shot fired from a 68-pr. S.B. gun, 16 lbs. charge at 30 feet range, and was reported A1 quality. It was subsequently removed to Shoeburyness, but was completely penetrated by a Palliser shot of 248 lbs. weight fired with a 43 lbs. charge. The minute on the experiment states that these results prove—

(1) That the 9-inch rifled M.L. gun is capable of completely perforating a 10-inch solid plate at 70 yards, when fired with the battering charge (43 lbs.) and Palliser shot.

(2) That Palliser projectiles can easily perforate plates thicker than their own diameter, with battering charges.

(3) That, although it would be premature on the result of one experiment to give a final opinion, it appears probable that a 10-inch solid plate offers, as now made, little if any more resistance than two plates of 5-inch bolted together.

In an experiment which was made at Shoeburyness in November, 1867, it was ascertained that two 5-inch plates bolted together will resist the penetration of a Palliser shot of the above weight fired from the 9-inch R. gun at 70 yards, with a 37 lbs. charge, but are penetrated when a 43 lbs. charge is used; and the following table gives the comparative results of the three experiments:—

Experiment.	Target.	Charge.	Penetration.
No.		lbs.	inch.
1	Two 5″ plates bolted together	25	5·5
2	Cyclops 10″ plate	"	5·55
3	Atlas 10″ plate.....	"	6·5
1		37	13·0
2	.....	"	8·6*
3		"	
1		43	total
2	.....	"	13·9
3		"	total

It will at once be seen that the results of these experiments cannot be taken as conclusive regarding the relative value of 10 inches of iron when used in one thickness, or in two 5-inch plates, but a few remarks may be made on the absolute results obtained. And first it may require explanation how 10 inches of iron can be penetrated to a depth of 13 inches, as shewn in the table, unless totally penetrated. The reason is that the 5-inch plates being merely in contact, part of the work of the projectile is used in forcing the plates asunder, and they become separated and bulged. Thus, whilst total penetration is prevented, the penetration and bulge is of a larger amount than the entire thickness of the plates.

* Shot badly chilled.

A curious anomaly resulting from these experiments is this: that a plate (No. 2) of *inferior* manufacture gave greater resistance than one of good manufacture (No. 3); for whilst we are told that "the first round caused the 10-inch plate to separate into two 5-inch plates, and the rest of the experiment was practically at a compound structure of two 5-inch plates," and again, that "the two 5″ plates," (of which No. 2 was composed) "appear to have been welded only at left top corner," this badly manufactured 10″ plate (No. 2) effectually resisted the penetration of two Palliser shot, fired with the full battering charge, whilst No. 3 was completely penetrated by a similar projectile.

As has been stated above, No. 3 plate was a sample of the contract taken by the Atlas Works for the supply of 10″ plates for the "Monarch," and passed successfully through the ordeal at Portsmouth, having been placed in the highest class, viz. A1. But after the results obtained at Shoeburyness, it seems doubtful whether the system still in use at Portsmouth of testing plates on wood backing with a light smooth-bore gun is any criterion of the real fitness of the plate for resisting rifled projectiles from heavy guns. Palliser projectiles from heavy guns fired at the plate in an unbacked state, seems a much more suitable and practical test.

Lastly, the 10″ plates gave conclusive evidence that the difficulty of obtaining perfect welds in thick armour plates is not yet overcome. The official report regarding No. 2 plate has here been quoted, and an inspection of No. 3 plate shews the like defect, though in a very much smaller degree. The correctness of the opinions expressed by Dr Percy in his book on Metallurgy,* published in 1864, has received entire confirmation to the present time.

"The difficulty of manufacture, for reasons previously assigned, greatly increases in proportion to the *thickness* of the plate. Tendency to lamination in rolled plates under the impact of shot is the great evil, which has not yet been effectually surmounted, if indeed in the very nature of things it be possible to do so. Plates which from an examination of their exterior have appeared perfect, have been broken and laminated to an extent which would hardly be credited by persons who have not witnessed the fact. This is due to imperfect welding of the contiguous surfaces of the layers of iron composing the plates, caused by interposed cinder, which however liquid it may have been in the re-heating furnace, it is not possible should ever be completely expelled, even if the surfaces of the superimposed component layers were perfectly flat and smooth like plate glass; much less is it possible since those surfaces are always more or less uneven."

50. Horse Transport.† The following information has been extracted from an Official Memorandum‡ forwarded to the Committee by Lieutenant Chapman, R.H.A.

Tenders for Transport Ships were opened on the 15th October, by the 30th idem fifteen ships have been allotted, to be ready for sea on the 10th November only one, however, was ready for Troops during the whole of that month. This chiefly is stated to have arisen "owing to the very indifferent workmen employed by the several Contractors" by which "continual alterations and condemnations had to be made".

"All this time the vessels were constantly, indeed almost daily, visited by the Transport Committee, who endeavoured in every way to hurry on the completion,

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* Iron and steel, p. 740.

† Vide No. 36, p. 39, for information on the same subject.

‡ Memorandum regarding the fitting out of the transport ships taken up for the conveyance of troops to Abyssinia, by Major Fred. Roberts, R.A., V.C., Assistant Quarter-Master General, Bengal Brigade, Abyssinian Expeditionary Force, Dated 31st December, 1867.

but owing to the very indifferent workmen employed by the several contractors, constant alterations and condemnations had to be made. The instructions regarding the number and size of the different stalls were not attended to, bad wood, small screws or nails. &c. were used wherever it was thought that the Committee would not discover the defects."

Major Roberts considers that these delays could be obviated to a great extent by the adoption of the following measures :

(1) Owners to be bound down by a heavy penalty to have their vessels ready on a certain date.

(2) That the vessel be made over entirely to Government to fit up, ventilate, &c.

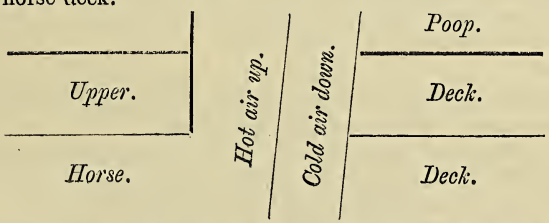
(3) The fittings to be Government property ; to be numbered when first put up, and returned into store when no longer required.

(4) If the ships are not fitted by government, the owners not to come on pay until the vessels are complete in all respects.

Selection of Ships. Those for artillery or cavalry to be as high 'tween decks as possible.

Six ships were required to convey a cavalry corps consisting of 9 officers, 13 native officers, 450 n.c. officers, rank and file, 3 native doctors, 489 horses, 322 mules, and 590 followers ; and four ships for an infantry corps of 9 officers, 16 native officers, 736 n.c. officers, rank and file, 3 native doctors, 10 horses, 350 mules, and 400 followers. Usually the troops were placed in the forepart as being the coolest, the horses and mules amidships, and the followers aft.

Ventilation. Bow-ports the best means ; openings also to be made on deck ; cut one, two, or three planks for a length of from 12′ to 40′, also a smaller space aft ; cover with a combing ; cowlheaded and Admiralty ventilators should be used, also two large double ventilating trunks should be made, one through poop and the other through forecastle. Windsails to be fixed in each hatchway, to be carried down to within 18″ of horse deck.



Cleanliness. Every tenth stall to be spare, to shift horses daily. Scuppers to be cut in deck behind to carry urine, &c. into bilge. Chloride of zinc and Macdougall's disinfecting powder the best disinfectants. 6 or 7 lbs. of the former and 3 or 4 lbs. of latter to be used daily. *Chloride of lime on no account* to be used. Stalls *not* to be whitewashed, but other parts of deck to be done every 10 or 12 days.

For Bilges. Mix 2 lbs. chloride of zinc with 5 gallons of water.

Macdougall's powder can be used dry or wet ; if dry, a good sized dredger is required, if wet, use 3 ounces to 1 gallon of water, or 5 to 8 ounces if strong solution is required. Pieces of old blanket saturated in a strong solution of this powder and hung up 'tween decks will purify the atmosphere.

Stalls should be washed daily, and scrape, or dry holy stone the portion of the 'tween deck occupied by troops

Stalls, 6′ 6″ long × 2′ wide.

Stanchions, 4″ × 4″.

Sideboard, 9″ × 1½″. Front or breast boards 9″ × 1½″. Lower front board, ditto. Kicking batten 2½″ × 2″. Deck battens, 2½″ × 1½″ (four for each stall, and to run along the width of 3 or 4 stalls).

Deck cant-pieces, in front and rear of stalls, $7'' \times 3''$. Rear rail, $4'' \times 3''$. Shores, $4'' \times 4''$. Cleats, $12'' \times 4'' \times 1\frac{1}{2}''$. Screws always to be used. Mangers (of $1\frac{1}{2}''$ plank), 9″ deep, 8″ wide at bottom, 11″ wide at top, 20″ long, bound with iron.

Hanging hooks for mangers, 2″ wide $\times$ $\frac{3}{8}''$ thick. Hay nets, $4' \times 3'$. *Head stalls*, one per horse, and 15 per cent spare.

Slings, 6 per ship. *Horse hammocks*, 25 or 30 per ship. *Coir mats* are not good for general use.

Mule stalls, 20″ wide. Length of manger 17″.

Fittings to be kept parallel to run of ship; side and front boards and kicking battens to slide easily into the cleats; a passage of 3 or 4 ft. to be left between rear stanchion and side of the ship.

51. Lieut.-Colonel Shaw's Muzzle-pivoting Carriage.

In a note which will be found at p. 260, Vol. V. of the "Proceedings" of the R.A. Institution, Lieut.-Colonel Shaw states, "that although one of his wrought-iron muzzle-pivoting carriages had been under trial on board H.M.S. "Prince Albert," for nearly a year, he had not been able to obtain any official information as to its efficiency or otherwise."

The following information has since been published.*

Captain Foley, of H.M.S. "Cambridge," reports that "after having given the iron muzzle-pivoting carriage on Lieut.-Colonel Shaw's design for 12-ton guns, on board the 'Prince Albert,' a good fair trial, with continuous battering charges at high elevations, he is of opinion that it is on a most excellent principle, and better adapted for working in a turret than the other iron carriages (on the single plate system of Royal Carriage Department make, for 12-ton guns, mounted on wood shifting platforms made in Woolwich Dockyard on Captain Coles' system), on board that ship, inasmuch as extreme elevations are easily obtained in three to five minutes; whereas, with the carriages in the other turrets, to give the same amount of elevation would take three quarters of an hour to lower the platform. He considers this of the greatest importance.

"The porthole in the turret, in which the muzzle-pivoting carriage is used, being very much smaller than the other turrets, is also a great feature in its utility, by lessening the chance of a shot entering the turret.

"In returning the above report on the trial of Lieut.-Colonel Shaw's muzzle-pivoting carriage, the O. S. Committee consider the result as highly satisfactory to the construction, as well as to the principle of muzzle-pivoting."

The number of rounds fired from the 9-inch rifled muzzle-loading gun mounted on the above-mentioned carriage, on board the "Prince Albert," were as follows:—

No of Rounds.	Elevation.	Charge.	Projectile.
		lbs.	
3	11° to 12°	43	Empty shell.
3	9	"	Filled shell.
8	5° to 6°	"	Empty shell.
6	9	"	Blank.
45	4° to 6°	30	Empty shell.
7	4	15	"
72			

Note.—In addition to the above, there has been fired from the carriage ten rounds, 14 lbs. charges, and projectile 256 lbs., at Woolwich, 27/11/65, and about forty rounds when the ship was commissioned by Captain Wilmshurst.

* Extracts from Proceedings of the O. S. Committee, Vol. V. p. 322.

52. Some Observations on the Mobility of Field Artillery.

The following remarks on the subject of the Mobility of Field Artillery have been forwarded by Lieut.-Colonel Soady, R.A. :—

It is proposed here to consider cursorily the present mobility of field artillery in the British service, as well as the tactical amount of celerity required from it when in support of the Arm it is specially attached to; whether it is with facility and sufficient celerity able to cover and protect its own infantry in changes of front or of position, or when advancing, as well as capable of being quickly and with but short warning brought together or re-inforced from the reserve to bear on important points of an enemy's position, or to act against those arms requiring formidable opposition.

1st, Are field batteries capable of affording other troops the utmost protection and support, or is their action restricted or limited from any cause?

Taking the case of an infantry brigade of three battalions with a field battery of light guns attached and in position on a flank.* The brigade in line would occupy rather over 700 yards with battalions of 800 strong,† to which must be added the distance for the front and interval of the battery.‡

Should the brigade be required to change front, and the guns from not having been previously on the pivot flank unable to correspond and be brought into action with the front clear within a short distance, then, unless the guns can move more speedily than the foot pace of the infantry towards their new position, the value of their cover will not be felt during the execution of the movement.

Should a change of front be made on a company of the centre battalion, the guns would have larger arcs to describe than the centre or either of the flank battalions, before the new position could be reached; advantage in pace would therefore be also essential here.

When a forward movement is to be made of both guns and battalions, the guns with their detachments on foot would still be unable to move at an accelerated pace when within effective range, in order to precede and cover the infantry from favourable positions for the better aiding their advance or taking the enemy at a disadvantage, consequently cover could not be afforded to the advancing troops without the undesirable contingency of the guns dropping to the rear and firing over the heads of the troops.

Napoleon says, "There is no infantry, however brave, which can without artillery march with impunity ten or twelve hundred yards against sixteen pieces of cannon well placed and well served; before it could accomplish two-thirds of the distance those men would be killed, wounded, or dispersed." Hence the necessity for the artillery not being retarded in its progress when supporting and

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* Field Exercise, 1867.

† Hand Book for Field Service, 1867.

‡ Gun detachments of field guns, when brigaded for manœuvres with other arms, are not mounted, but remain on foot; the ammunition wagons do not remain with their guns on these occasions, but are kept at a distance in rear, protected from the enemy's fire as far as the ground permits.

clearing the way for other arms; occupying secure positions on a flank, in advance, or commanding points without obstruction.

Artillery moving in a mass towards the front, of from 30 to 40 guns, four batteries of field artillery and two batteries of horse artillery, with the view of coming into action at a crisis, or breaking any part of an enemy's line. Should they be formed into two separate columns of attack, the batteries of field artillery moving only at a walk would if at all opposed by the enemy's artillery be liable from the prolonged exposure to suffer considerable losses in guns alone, previous to deploying and unlimbering. The battle of Wagram may be cited in support of this, where out of sixty pieces of artillery which the French in the first instance advanced to the front for the purpose of breaking the Austrian centre, fifteen pieces were dismounted before unlimbering. Six foot and four horse artillery batteries composed this mass; the latter we are told advanced at a trot, but the former at a walk.*

Jomini says, "When the cannoneers can mount the boxes it may have greater mobility and be advanced further to the front."† "It would frequently be impossible to attack an enemy if he had sufficient warning of the design to prepare to oppose it." . . . . "The general engagement once begun," says Napoleon, "he who has the address to bring suddenly and unknown to the enemy an unexpected amount of artillery to bear upon the most important points, is sure to carry them. This is the secret of '*la grand tactique*.' "‡

"There is usually great advantage in keeping our batteries constantly shifting their position, for then they have the effect of a surprise by opening on the enemy at some unexpected point; they make the enemy believe our guns to be more numerous than they really are; they are in less danger of being captured."§ Changing position must depend upon circumstances, but the advantage of *possessing the means of doing so with celerity*, that is, faster than men can proceed on foot, can hardly be disputed. "The movements of a battery in the field should be as rapid as possible, for while moving it is helpless and exposed."§ The effect of its fire is also withheld during the movement.

"Considering the progress made by artillery in mobility and range, late French writers of authority assert that to associate it intimately in future with infantry would fetter its power and diminish its utility."‖ The German campaigns of 1866 testify to its importance and the support expected, from the great numbers of guns employed and brought into use on both sides. Again, quoting Colonel Hamley, "To gain from this mobility its greatest effect, field batteries should to a certain extent be converted into horse artillery, by which the greatest possible rapidity of manœuvre would be attained, batteries would constantly shift their position, so as always to take the line diagonally or in flank, and by rapid retreat could baffle a counter attack."

Taubert says on this matter "that the men should be mounted in an engagement, "in order to increase the mobility of foot artillery to the utmost on the field of battle both in advancing and coming into a position for action, as well as in retreating when foot artillery in its moment of need, is endangered in its

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* Taubert.

† Jomini's "Art of War." Chapter VII. Art. 46, par. 2.

‡ Hamley's "Operations of War," p. 381.

§ Lippit, "Tactical use of the Three Arms," pp. 71, 72.

‖ Hamley's "Operations of War," pp. 395, 396.

position after a long struggle, or when it has to take up a position quickly to the rear."

The full amount of protection and support to be obtained from field batteries of light guns would therefore appear to depend upon their means of mobility not being too limited, permitting these guns to be moved when circumstances require them from position to position within proper limits and with their escorts, at an increased rate of manœuvre over the battalions of infantry, that is at a *trot*, and to be capable of opening fire at an early moment instead of proceeding at the ordinary pace of infantry.*

Batteries of light field guns usually composing the greater proportion of artillery employed in the field, and being organized on an economical establishment of horses, it becomes of weighty consideration when conducting a campaign to have their mobility and celerity of movement fully developed, thereby increasing the utility of the bulk of the artillery.

2nd, As under the present system gun detachments of batteries of light field guns are unable to move with celerity from being on foot, thereby impeding the movement of the guns, what method of mounting the gun detachments can be considered without adding to the existing equipments, or requiring additional men or horses to be brought under fire?

The rate of manœuvre of each gun carriage aud limber with its six horses in draught, a mounted No. 1 and two limber gunners being controlled by the six remaining gunners of the detachment on foot; the guns with the horses and detachments are consequently liable to be exposed longer to the fire of an enemy without replying in taking up a position, than if the movement was performed with more celerity; the services of the guns are also partially lost by the increased time occupied by the movement; also the gunners instead of being fresh when required to open fire, must be, according to the distance passed over, more or less out of breath and exhausted, and physically unfit to lift a trail, man the wheels, or bring up a round of ammunition. To these serious drawbacks, may be safely added inability to commence firing with precision and coolness, or to be equal to maintain it; thus, the mobility and utility of the guns are impeded and lessened, by the non-mobility of the gun detachments.

Methods of conveying gun detachments with batteries of light field guns, to enable both guns and detachments to move at a pace more accelerated than infantry, have been carried out, by the off horses of the guns and ammunition wagons having been made available for the gunners; also by the gun axle-tree boxes having seats provided for the gunners. The application of both systems had for many years ample trials under all the experiences of war and peace,† although the former was in opposition to the principle of the weight on the back of a horse, being the worst application of the animal's strength, and to the very important matter of one man driving each pair of horses. Such a system of carrying gunners on the off horses, also appears to be put in practice at times with the Prussian horse and field artillery, which are closely assimilated and separated from the garrison artillery.‡

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* At Magenta and Solferino in 1859 masses of artillery were manœuvred under the protection of cavalry.

† The provision for mounting gun detachments, as will appear, is only intended when required to move at an accelerated pace during manœuvres in the field when about entering into action, on which occasions the ammunition wagons are not available.

‡ Professional Tour of Officers, R.A. 1865.

To enable this plan to be practically applied in the British service, would any essential points in training, clothing and equipment be required to deviate from the present system ?

Field artillery being liable to receive draughts of gunners direct from garrison and depot brigades, who have not had opportunities of crossing a horse or becoming acquainted with their care and management, it follows that the smallest knowledge only of mounted duties should be looked for from gunners transferred under the present system, to permit of their being tolerably efficient from the period of transfer.

The reflection may cross the mind, that this would only be likely to occur as an exceptional case, and that gunners would in the ordinary course of their training with established field batteries, learn sufficient equitation to be able to ride on an emergency or when expedient. To this it may be stated in reply, that what has occurred in recent years when field batteries have been called upon to take the field and be maintained there, as in the Crimea, and of still later date whilst serving in India, or even nearer home, will without change of system occur again; moreover, that field brigades are at all times liable to receive as effective transfers to complete establishments, fill up casualties, &c. gunners from depot brigades, where instruction in garrison duties is chiefly given.

With established field batteries, time and opportunity enable gunners to become well acquainted with the care and management of horses, so essential and important, and many of them become good horsemen; but as a course of equitation in the field artillery has been deemed hitherto alone requisite for non-commissioned officers and drivers, gunners do not undergo usually such instruction, and they do not receive overalls as part of their clothing, as do the recognized mounted ranks—non-commissioned officers and drivers.

This plan, from the forgoing therefore necessitates,—

(1) That the gunners of field brigades, or a proportion of them selected, should be put through a course of riding drill as well as the drivers, and to the same extent as the other mounted branches of the service.

(2) That those selected for mounted duties should receive mounted kits, in the same manner as other mounted men.

(3) That the establishment now existing at one of the depots for the purpose of specially instructing in equitation, &c. drivers intended for field brigades on foreign service, or about proceeding there, should be made also available for gunners intended for similar field brigades.

These three requirements would involve some slight change in the present system, and a slight increase, "probably insignificant," in expenditure, under the head of clothing.

There is yet another minor matter of detail, which would have to be provided for in marching and full dress order; the removal of the drivers valises from the off lead and centre horses of the gun teams; a convenient and suitable place for the carriage of which would have to be selected.*

It may also be desirable further to remark, that without the first of these requirements being properly carried out, efficiency cannot be expected—the rough and ready style of men unaccustomed to ride, or even mount, is unsuitable and only

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* With the latest patttern harness, there is but one description of saddle, both for ride and hand horses.

retards progress. Inexperienced drivers moving off, frequently are the cause of delay and mishaps; what then may not reasonably be anticipated from men altogether untrained and without practice, called upon to mount and move off in a hurry, over whatever ground may lay in the way.

The weight of three additional gunners on the gun carriage and limber, taking each man at twelve stone, would be 4½ cwt.; this weight distributed, two-thirds on the axle-trees of the gun, and one-third on those of the limber, would bring the total weight liable to be carried about 27 lbs. in excess of that carried with the 24-pr. howitzer, and a weight on the gun axle-trees less by about 2½ cwt. than that of the 9-pr. S.B. bronze gun, and less by about 2 cwt. than that of the 24-pr. bronze howitzer.*

This arrangement for a gun detachment of six, viz. the No. 1 mounted, three men on the gun limber (the same number as now laid down to mount on the wagon limbers) and two on the gun axle-trees, permits of a detachment of similar strength as with the off-horse system being carried with the gun whenever specially required, enabling officers in command of batteries of light field guns when called upon to move to any particular point with celerity, to be able to comply with the order, and not to be dependent on chance, and straggling gun detachments for the means of working the guns perhaps in the face of an enemy, after having proceeded at an increased pace.

The following may be taken as nearly about the bearings on the back band of a shaft horse; the limber packed in marched order, with knapsacks and great coats of two limber gunners, strapped on in rear:—

12-pr. Armstrong gun, 8 cwt.

Limber alone, gun unlimbered					94 lbs.
Limber, with gun limbered up					81 "
"	"	2 men	mounted		99 "
"	"	3	"		118 "
"	"	3	"	one facing the rear	100 "
"	"	3	"	a fourth on trail	107 "
"	"	3	"	and inclining bodies forward	133 "

The third limber gunner increases the bearing about nineteen pounds, when seated in the ordinary way, and when seated with his back to the two others, by one pound; in fact, counteracting any increase by a re-adjustment of the balance of the limber, and bearing on the back band. These bearings are under those given in the "Hand Book for Field Service," 1867, and may partly be accounted for from the gunners in the latter case, having their knapsacks on when seated on the limbers, which would have a tendency to cause their bodies to be inclined forward, as well as increasing the weight of the men, and throwing additional strain on the front of the limber.

The plan of carrying two gunners on the gun axle-trees is practised by the Danish and Prussian Artillery,† also by the Belgians; it has been also the custom in Bengal for many years. The special Committee of Artillery Officers, which was held at Meerut in 1859–60, to consider the organization, detail, and equipment of Artillery in India; three members, including the President,‡ belonging to the Royal Artillery, the other three members to the Bengal Artillery, have recorded

* Hand Book for Field Service, 1867.

† Professional Tour of Officers, R.A. 1865.

‡ The late Colonel Sir George Barker.

their opinion as to carrying a portion of the gunners thus, in the following manner :—

The Royal Artillery having reached India during the eventful year 1857, frequent opportunities of working on this plan presented themselves. The Committee say, on the matter of the equipment of carriages.—"The boxes on the gun axle-trees to be of the Bengal pattern, and one that on the near side to be fitted to carry a few rounds of ammunition . . . Both boxes to be made into seats for gunners in case of emergency; this will be practicable even with the 9-pr. gun and 24-pr. howitzer, in consequence of the increased space between the wheels and cheeks of the carriage from the use of the smaller ordnance. Guard irons must be attached to the axle-tree, to protect the men's arms from coming in contact with the wheels. It must however be understood that these boxes are not to be used as seats for drill purposes, but as an expedient for an emergency only when it may be required to take the guns forward at an increased pace, when by carrying two men in this manner, and three upon the limber, with the assistance of the mounted non-commissioned officer, the gun can be quickly brought into action, and served with effect. The men will be fresh for the purpose, instead of being distressed and blown, as is now the case, even if they are able to keep up with the gun at all, unless the ammunition wagon is brought under fire, but by which arrangement will be rendered unnecessary."

The space required between the cheeks of the carriage and the spokes of the wheels must be sufficient to admit of the lids of the axle-tree boxes being made from 14 to 15 inches wide, and about 18 inches in breadth,* from front to rear, furnished on the seat with a folded blanket, or some soft and yielding material.† A foot rest should be added in the form of an iron stirrup, or support fixed to the carriage or suspended from it, similarly to the breast chains; guard irons for the hands, about 9 inches high, secured to the outside and backs of the boxes, are also needful. On many matters connected with the equipment of Horse and Field Artillery, the members of the Special Committee alluded to differed, and their separate views are recorded in the Proceedings, which were published, but as to the advantages of providing the means for mounting the gunners in cases of expediency, they appear to have been unanimous. Should a battery with its detachments mounted in this manner, prepared for, or during an engagement, come upon swampy or heavy land, or rough and difficult ground, the gun detachments would dismount and be prepared to assist the guns if necessary.

In the Prussian service, the gunners are mounted for action at distances varying from 200 to 2000 paces. "Under 200 paces the object is more quickly obtained by making the men run, and over 2000 paces it is best to assume the forced march formation."‡ The forced march formation alluded to is used by the Prussian field artillery for forced marches, turning flanks, &c. or advances from the reserve, and is composed of the guns, ammunition wagons, and a portion of the gunners, sufficient for entering into an action; the store wagons, carts, spare men, artificers, and spare horses follow.§

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* Sufficient space exists with the 12-pr. Armstrong B.L. gun carriage.

† The Prussians appear to use buffer plates under these seats, as stated in the Professional Tour of Officers, R.A. 1865. The plan of strapping on a blanket, has been found, with us, sufficient on the limbers and wagon bodies. The axle-tree boxes being secured to the axle-tree bed with us, a back stay is not needed.

‡ Taubert.

§ In advancing for action, the ammunition wagons in the Prussian artillery are thus disposed of:—At within 1000 paces of the position to be occupied, the wagons are halted and formed into

In this paper the opinions of various authorities have been cited in favour of the advantages and necessity of possessing a system enabling batteries of light field guns to be moved with celerity, still later experiences affirm the necessity. It may reasonably be inferred, that field artillery with superior facility of movement, would be able (to use an ordinary phrase), to trot round a similar arm possessing only inferior powers of movement, and that on ground favourable to the performance of manœuvres, unless field batteries are able to move with as equal facility and celerity as those opposed to them, they must contend under great disadvantages.

The increased efficiency considered to be attendant on field artillery which has had its mobility extended to the utmost, has here been endeavoured to be brought forward, and as it is important and desirable to practice in drills and field movements what would be advantageous and requisite on actual service, so should field batteries be accustomed and required for purposes of manœuvre to work with mounted gun detachments independent of their ammunition wagons. Of what avail will it be having guns better horsed, if the pace is restricted to that of the gunners on foot, unless the latter are to be left straggling* and out of breath behind? Whatever numerical deficiency in guns may be expected, should be compensated for by their excellence in every point; with the advantages of throwing a heavier projectile and bringing but few men and horses under fire, "which from the multiplied fire and effective long range of breech-loading rifles has become so important," possessing the means of celerity of movement, would by increasing their utility tend to counteract disparity of numbers.

Without the development of their mobility field movements cannot be executed with adequate velocity, nor can the ground be passed over at a quicker rate than infantry; batteries of light field guns can be the more readily closed upon by an enemy's infantry sufficiently near for a destructive fire; they are also subject to the disadvantages arising from slowness in manœuvring, rendering them merely light guns of position.

The most favourable action of artillery with an army in the field formed in line of battle, must depend on the natural features of the ground permitting its employment, as well as on the order of battle adopted; the latter must chiefly determine the share it may be required to take in a combat, by the positions which can be advantageously occupied.

As in the attack of an army posted on commanding ground, or on the contrary when defending a position with a gentle slope and overlooking the ground over which an enemy must advance to the attack, the effective action of the artillery is exactly opposite; so it will be assumed for the purpose of these remarks, that the locality is a plain or sufficiently well adapted for the favourable employment of the arm, by the assailants, as well as their opponents.

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two detachments; the first detachment follows at 300 paces distant, if the battery unlimbers the detachment retires to a selected position from three to four hundred yards further to the rear. The second detachment of wagons keeps from 1000 to 1500 paces to the rear.

* Vide Kingslake's "Invasion of the Crimea," Vol. II. p. 403. Battle of the Alma. "The two guns for which Lord Raglan had prayed were brought up at length to the summit of the knoll. They were guns belonging to Turner's battery, and they were already crossing the river when Dickson came upon them. The two pieces were soon unlimbered; and one of them—for the artillerymen had not all been able to keep pace—was worked by Dickson with his own hands."

With the parallel order of battle, in which the two hostile lines are simply brought into direct contact, by the advance of one line towards the other, without any point or wing being selected as the decisive point to be attacked, with the main strength of the assailants; the amount of tactical movements which would be required from either of the arms would not be likely to be important. A combined forward movement under cover of the divisional artillery, from favourable positions, without any special portion of the opposing line to be broken through, would complete usually the dispositions for the attack, in the parallel order.

The concave and convex orders,* the former of which would hardly be adopted, unless to oppose an enemy who might use the convex or salient order of attack—when, by advancing the two wings, the concave order would be assumed by the force awaiting the attack;—the convex order being assumed after the passage of a river, or in an endeavour to break an opponent's centre. With these orders of battle echeloned respectively on both wings, or on the centre, opportunities according to the amount of opposition met with, should present themselves, requiring changes of position, taking the opponents obliquely by the divisional batteries, or by batteries assembled and massed with sufficient celerity, when necessary to bear on an important point.

The oblique order of battle† for the purpose of turning an enemy's flank, bringing sufficient force to overthrow one of the wings, would be also considerably strengthened by a strong force of artillery supporting the head of the attack, suddenly occupying points—principally on the inner flank—and opening fire, under the protection of escorts, placed so as to generally conform to the disposition of the attacking force, taking their opponents by a cross fire, again limbering up and continuing the attack elsewhere. The dispositions of the artillery of the army attacked would also of necessity have to be speedily made. A change of front of the wing assailed, under the immediate cover of its own divisional artillery; reinforced subsequently by available batteries—"heavy and light"—quickly collected and moved towards the assailed flank, to oppose the full force of the attack.

Here then, in these modern methods of offensive and defensive battles, operating against a wing,‡ against the centre,§ or against both wings, the artillery on both sides may have most important functions to perform; dependent as materially on their mobility, as on their weight of metal and calibre.

53. Resistance of the Air to the Motion of Projectiles.‖

The following Tables, derived from experiments made with Professor Bashforth's Chronograph during the present year, shew the connection between initial velocity and weight of charge for the 9-in. M.L. rifled gun with the service shot; and the velocities of the service shot for the 9-in., 8-in., and 7-in. M.L. rifled guns at intervals of 100 feet, supposing the shot to move in a straight line.

Their use may be seen from the following examples :—

Ex. 1. The velocity of a 7-in. service shot being 1500 f.s. at some observed point of its path, what will be its velocity at a point 1000 yds. distant?

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* Adopted by the Federal Army, strongly posted, at the battle of Gettysburg.

† The celebrated battle of Leuthen by Frederick the Great.

‡ The Prussian Right at Ligny and the English Left at Waterloo, were first attacked by Napoleon.

§ This form, aided by one on a wing, gave Wagram and Ligny to Napoleon.

‖ Communicated by Captain Ford, R.A.

In the last Table, corresponding to 1499 f.s. (the nearest velocity to that observed) we find 2200 ft.; adding to this 3000 ft. we obtain 5200 ft., opposite which in the Table we have the velocity 1252 f.s. The velocity required therefore is 1253 f.s.

Ex. 2. A shot from a 9-in. gun at 200 yds. is required to strike with the same velocity as would be given by a charge of 43 lbs. at 1000 yds. What should be the charge?

From the first Table we see that 43 lbs. gives an initial velocity of 1314 f.s. this velocity is reduced to 1162 f.s., at 3000 ft. (by the second Table): this is the striking velocity. The initial velocity at 600 ft. (by the same Table) should be 1190 f.s. The charge therefore clearly (by the first Table) is 30 lbs. 3 oz.

Table shewing the connection between initial velocity and weight of charge for the 9-in. M.L. rifled gun, with the service shot. Obtained by interpolation.

Charge.	Initial velocity.	Charge.	Initial velocity.	Charge.	Initial velocity.
lbs.	f.s. Δ_1	lbs.	f.s. Δ_1	lbs.	f.s. Δ_1
20	959	29	1171	38	1274
	+31		+16		+ 8
21	990	30	1187	39	1282
	+29		+15		+ 8
22	1019	31	1202	40	1290
	+27		+13		+ 8
23	1046	32	1215	41	1298
	+25		+12		+ 8
24	1071	33	1227	42	1306
	+24		+11		+ 8
25	1095	34	1238	43	1314
	+22		+10		+ 8
26	1117	35	1248	44	1322
	+20		+ 9		+ 7
27	1137	36	1257	45	1329
	+18		+ 9		
28	1155	37	1266		
	+16		+ 8		

Tables shewing the velocities of the service shot (ogival head) for the 9-in., 8-in., and 7-in. M.L. rifled guns at intervals of 100 ft., supposing the shot to move in a straight line.

9-in. M.L. rifled gun.

Diam. of shot, 8·92 inches. Weight of shot, 250 lbs.

Distance.	Velocities									
	0	100	200	300	400	500	600	700	800	900
feet.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.
0	1400	1394	1387	1381	1375	1368	1362	1356	1350	1344
1000	1338	1332	1326	1320	1315	1309	1303	1298	1292	1287
2000	1281	1276	1271	1265	1260	1255	1250	1244	1239	1234
3000	1229	1224	1219	1214	1209	1205	1200	1195	1191	1186
4000	1181	1177	1172	1167	1163	1159	1154	1150	1145	1141
5000	1137	1133	1128	1124	1120	1116	1112	1108	1104	1100
6000	1096	1092	1088	1085	1081	1077	1073	1070	1066	1062
7000	1059	1055	1052	1048	1045	1041	1038	1035	1031	1029
8000	1025	1021	1018	1015	1012	1009	1006	1003	1000	997
9000	994	991	988	985	983	980	977	974	972	969
10000	967	965	962	960	957	955	953	950	948	945

8-in. M.L. rifled gun.

Diam. of shot, 7·92 inches. Weight of shot, 181 lbs.

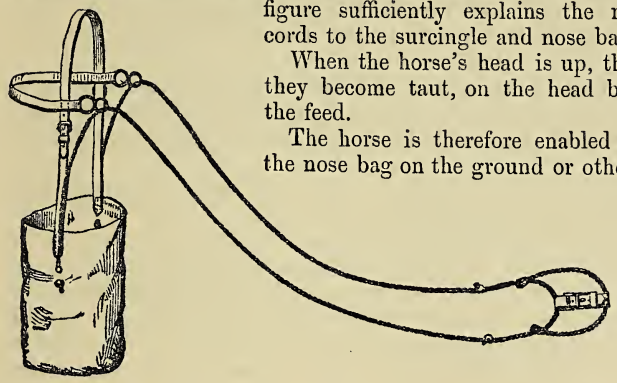
Distance.	Velocities.									
	0	100	200	300	400	500	600	700	800	900
feet.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.
0	1700	1691	1683	1674	1666	1658	1649	1641	1632	1624
1000	1616	1608	1599	1591	1583	1575	1568	1540	1552	1544
2000	1536	1528	1520	1512	1504	1497	1489	1481	1474	1466
3000	1459	1452	1444	1437	1429	1422	1415	1407	1400	1393
4000	1386	1379	1372	1365	1358	1352	1345	1338	1331	1324
5000	1318	1311	1304	1298	1291	1285	1279	1272	1266	1260
6000	1254	1248	1242	1236	1230	1224	1218	1213	1207	1201
7000	1196	1190	1184	1179	1174	1168	1163	1158	1153	1148
8000	1143	1138	1134	1129	1124	1120	1116	1111	1107	1103
9000	1098	1094	1090	1086	1082	1078	1074	1070	1066	1063
10000	1059	1056	1052	1049	1046	1042	1039	1036	1033	1030
11000	1027	1024	1021	1018	1015	1013	1010	1007	1005	1002
12000	999	997	994	991	989	986	984	981	979	976
13000	973	971	968	966	964	961	959	956	954	951
14000	949	947	945	943	941	939	937	935	933	931

7-in. M.L. rifled gun.

Diam. of shot, 6·92 inches. Weight of shot, 115 lbs.

Distance.	Velocities.									
	0	100	200	300	400	500	600	700	800	900
feet.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.
0	1717	1706	1695	1685	1674	1663	1653	1643	1633	1623
1000	1613	1603	1593	1584	1575	1565	1556	1546	1537	1527
2000	1518	1509	1499	1490	1481	1472	1463	1455	1446	1437
3000	1428	1419	1410	1402	1393	1385	1377	1368	1360	1352
4000	1344	1336	1328	1320	1312	1304	1296	1288	1281	1273
5000	1266	1259	1252	1244	1237	1230	1223	1216	1209	1203
6000	1196	1189	1183	1176	1170	1164	1157	1151	1145	1140
7000	1134	1129	1123	1118	1113	1107	1102	1097	1091	1186
8000	1081	1076	1071	1066	1061	1056	1052	1048	1045	1041
9000	1038	1034	1031	1028	1024	1021	1018	1015	1011	1008
10000	1005	1002	999	996	992	989	986	983	980	977

54. Nose Bag, in use in Prussia.* A method for a nose bag, is now in use in Prussia, called "Neuer Futtersack nach dem system Moque." The figure sufficiently explains the mode of attaching the cords to the surcingle and nose bag.



When the horse's head is up, the cords are loose, but they become taut, on the head being lowered to get at the feed.

The horse is therefore enabled to eat without placing the nose bag on the ground or other rest.

55. Penetration of Earthen Parapet by Heavy Rifled Guns,† at 70 yards range :—

A 10″ Palliser shell, head 1·5 D, weighing 398 lbs., fired from a 10″ M.L. rifled gun of 18 tons, with a charge of 54 lbs., penetrated 23 feet of earthen parapet, and passing out in an upward direction, fell 300 yards beyond.

A 9″ Palliser shot, head 1 D, weighing 248 lbs., fired from a 9″ M.L. rifled gun of 12 tons with a charge of 37 lbs., nearly passed through 23 feet of earth, the point of the shot showing through on the inner side of the parapet.

56. Specimens of Foreign Woods. An interesting addition has been made to the museum of the R.A. Institution by the presentation of specimens of foreign woods from British Kaffraria by Lieut.-Colonel Chermside, R.A., from the Bombay Presidency by Capt. Hobart, R.A., and from New Zealand by Captain Betty, R.A. The descriptions received from Lieut.-Colonel Chermside and from Capt. Hobart are here printed, and Lieut.-Colonel Chermside "is convinced from long experience that many of the Cape woods would give great satisfaction for the construction of Military Carriages to be used in warm climates."

‡ In the forests of the Cape of Good Hope are found several varieties of trees, the woods of which are of considerable value for numerous purposes, useful as well as ornamental. Among the former may be reckoned timber possessing qualities particularly adapting it for the construction of wheeled carriages.

The large wagons used by the Dutch farmers, are made entirely of Colonial woods, and the services which these wagons have to perform require that the several parts should be of the best possible materials. The very dry atmosphere of the Cape, the hot sun, and, still more, the extremely rough roads, try to the utmost all conveyances used in the Colony; and it is not too much to say that woods which can stand such tests as they there undergo, would endure in all similar extreme climates.

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* Communicated by Lieut.-Colonel R. Curtis, R.A.

† O.S. Committee Extracts. Part 1, Vol. VI. p. 86.

‡ Memo. upon the woods of British Kaffraria, to accompany thirty-eight specimens presented to the R.A. Institution by Lieut.-Colonel Chermside, R.A.

For instance, the yellow wood (two varieties), is invariably used for naves. It is a light wood, pithy, cross-grained, and wanting in fibre, and when cut into planks is much inclined to warp, yet it answers admirably when used for naves. It is durable, holds the spokes firmly, and is not liable to split when exposed to the sun or to the hot winds.

For spokes, the red pear or white pear is found to answer exceedingly well, being close-grained, tough, and does not split. Felloes are made from the milk-wood (two varieties), it is close-grained, hard, and wiry in fibre, very durable when well seasoned.

Poles or shafts are made of white iron wood. This is a heavy compact-grained wood, very strong and tough, though rather heavy for shafts.

On the failure of the (so-called) Kaffrarian equipment sent from England to the Cape in 1864, wheels and shafts for artillery carriages were constructed by the artificers of the battery from the above woods, using the iron work from the numerous unserviceable wheels. The wheels thus made seemed likely to outlast many sets of those received from England, which were made of a wood called "pedook," the failure of which, whether as shafts, felloes, naves, or interior fittings of limber boxes, was complete.

Rough spokes, felloes, naves, &c. cut and seasoned in "the bush," can be delivered at the military station of King William's town for a very small sum, and from thence the land carriage to East London, the port of embarkation at the Buffalo Mouth, is about forty miles. The freight to England would be inconsiderable. The Commissariat Department, who use all the above-mentioned woods for the construction of their own excellent transport carriages, could furnish any quantities, should it ever be determined to try the qualities of the Kaffrarian woods for the manufacture of artillery carriages. Experiments in this direction would not be costly, and might lead to important economical results.

Sneeze wood. A tough, compact-grained wood, extremely resinous. This wood when used for piles in water or damp ground, endures for an indefinite period. A splinter will burn like a torch, the heat causing the resinous sap to fall from it in drops. It is much sought after for building purposes, and for fuel. It is unfortunately scarce, and is of slow growth; it is a most valuable wood. Any one sawing or using sand-paper to it, will at once understand the reason of its peculiar name.

Olina and wild olive, are close-grained hard woods; can receive a high polish, very ornamental, and durable. Much used for building purposes.

Stink wood, black and red. Handsome dark woods, something like mahogany, used for furniture, sides of wagons. &c.; a valuable wood.

Black iron wood. A heavy, close-grained wood, veined with dark streaks; very ornamental.

Black Bast. A light grey wood, remarkable for the jet black streaks running through it. Is not common. A very handsome, ornamental wood.

Mimosa. The wood of the thorny mimosa, (*mimosa horrida*); from this tree is procured the African gum of commerce. The wood is of little value, excepting for fuel, for which it is largely used.

Wait-a-bit. The Dutch "wachum bitche," the wood of the formidable thorn tree, which bears its claw-shaped thorns in double rows along each branch, the points being turned in different directions. This most vexatious of prickly shrubs, rarely attains to the dimensions of a timber tree, but the wood is of a very handsome dark shade; it is hard and takes a high polish. The umtati, under bush, lemon wood, wolves' thorn, clip-else, Kaffir plum, sugar bush, assegai wood (from which the Kaffir assegai handles are made), and the aromatic, sweet smelling umtamboti, &c. all forming part of this collection, require no detailed notice, they are all exceedingly pretty and ornamental.

SPECIMENS OF DIFFERENT WOODS FROM THE BOMBAY PRESIDENCY.*

No.	Botanic names and classification.		Indian names in common use.	General description and uses.	Uses for ordnance carriages.
	European.	Indian.			
1	Acacia Arabica Mimoseæ.	Curvaila Marum.	Babool.	A very common wood, extensively known. It is very hard, but is too small for most purposes, principally used for ploughshares and naves of wheels. It makes good charcoal.	Felloes. Naves. Fittings of boxes.
2	Vachellia Farnesiana. Acacia Farnesiana. Mimoseæ.	Veda Vully Marum.	Edy, or Tree Babool.	This is of the same species as the last, but inferior to it in size, and is used for agricultural implements, house material, &c. When growing it is distinguishable from the first by its more horizontal mode of branching; the smaller branches long and stretched out, the side branchicles from them going off at right angles, nearly. The bark also is much more reticulated, broken, and corky, than that of the other. The pod and tender branches of both species form an important article of food for sheep, goats, and cattle. The produce of the Babool preserves is sold in Feb. and March, and the shepherds and goatherds are after the sale allowed to pasture their flocks on these branches and pods till late in May. The flesh of lambs fed on the pods has a flavour equal to that of the best European lamb. There is also a scrubby shrub of this name, but it is not applicable to any other purpose than tent pegs and fire-wood.	
3	Acacia Odoratissima. Mimoseæ.	Curry Vaugay Marum.	Sofaia Mutty. Sirrus.	A dark coloured, strong, and heavy wood, takes a good polish, can be obtained in considerable abundance, and of good size, viz. about 1 ft. square beams. It is well fitted for naves of wheels. It sustains 570 lbs. per inch bar.	Naves. Trails. Perches.
4	Dalbergia latifolia. Leguminosæ.	Erooppoottoo Marum.	Seesoo, or Seesum (Eng.) Black Wood.	A very dark wood, heavy and strong. It is extensively used for cabinet work, knees of vessels, agricultural implements, combs, &c. It sustains 515 lbs. per inch bar.	Trails. Perches. Axletrees. Cheeks. Splinter bars.

* From a Pamphlet by Dr Gibson, Curator of Forests, Bombay. Communicated by Lieut. Bertie Hobart, R.H.A

No.	Botanic names and classification.		Indian names in common use.	General description and uses.	Uses for ordnance carriages.
	European.	Indian.			
5	Dalbergia. Sissoides. Leguminosæ	Eatty, or Vitty Marum.	Nurrum Seesum.	The same as the last, but not so valuable. Used as rosewood in furniture.	
6	Ptero-carpus. Marsupi-num. Legu-minosæ.	Vengay Marum.	Hoonee, or Hussum, or Beebla (Eng.) Honey Wood.	A very large and beautiful tree, especially when in flower. The wood is dark coloured and strong; but it requires to be kept dry, as it will not stand exposure to wet. It gives out to wet lime (whitewash for example) a dark, misty, brown colour, which deteriorates it for house building. It yields a resinous substance, which is collected in large quantities in Malabar, and sent to England under the name of Kino. It sustains 370 to 400 lbs. per inch bar.	
7	Tectona grandis. Verbenaceæ.	Teak Marum.	Teak, or Sagwan. Saya. Sag.	In endurance under exposure it seems superior to all other Indian woods. Differences in quality, according to latitude, soil, or situation, are very observable. It sustains about 400 lbs. per inch bar.	
8	Gruelina Arborea. Verbenaceæ.	Coomy Marum.	Sewanny. Shewun.		
9	Pentaptera glabra. Terminaleæ.	Curry Murah Marum.	Curry Mutty, or Colla Mutty. Aeen. Mairtee. Sadura.	A large tree, wood dark coloured, very hard, heavy and strong, procurable in large beams for house building. It sustains 430 to 450 lbs. per inch bar.	Trails. Perches. Spokes. Shafts and poles.
10	... ...	Eroovaloo Marum.	Gugil, or Yerool. Jamba.		
11	... ...	Mitch Marum.	Morarty. Makur limbo. Kat yelloo.		
12	... ...	Pillah, or Peela Marum.	Colla Plas (Eng.) Jack Wood.		

57. *Relative Powers, by Computation, of the Service 9″ and 10″† M.L. rifled guns. The results show :—

(1) That the 10″ projectiles would strike a harder blow at 2000 yards than the 9″ would at the muzzle.

(2) The power of perforation possessed by the 10″ shot or shell at 1500 yards is the same as that of the 9″ at the muzzle.

* O.S. Committee Extracts. Part 1, Vol. VI. p. 86.

† Eight of these guns form the armament of H.M.S "Hercules."

58. Experiments carried on at Woolwich, as to the question of issuing Shells filled and plugged, or empty, with Fuzes screwed in, for Land Service.*

The following are the results of a trial made to ascertain whether, in the event of ignition of the gun cartridges in a limber box, either by accident or design, the danger to the gunners and troops in close proximity would be much increased if the surrounding shells were carried filled, and plugged, instead of empty and the bursters in the cartouch.

Two 40-pr. limber boxes, packed as for service, as regards their ammunition, the one having its shells loaded and plugged, the other empty and the bursters in the cartouch, were first travelled fifty miles (it being considered that the travelling might possibly loosen the plugs), and then without being opened were exploded by firing into them with Metford's bullets, in the exact condition in which they were returned from travelling.

(1) The 40-pr. limber box carrying the loaded shell was first exploded.

It was fired the first round. None of the loaded shells exploded; the lifting straps round them were not even injured. The shells were dispersed within a radius of six yards. The top of the limber box was blown to a distance of nineteen yards.

(2) The 40-pr. limber box carrying empty shell and the bursters placed in the cartridge cartouch as at present obtains in the service, was next fired; it was exploded at the fourth round.

As was anticipated the explosion was much more violent, the quantity of powder in the cartouch being increased from 25 lbs. to 37½ lbs.

The shells and wood splinters were blown to distances varying from 25 to 30 yards.

The straps round the shells were blown away and completely charred.

From these results it has been ordered that the shells of field artillery and batteries of position shall, in future, be carried in the limbers loaded with plugs in their fuze holes.

59. Notes on Field Artillery.† These few remarks are offered to the notice of my brother officers with considerable diffidence, as they are merely notes made on the part played by our own arm, in the Campaigns of 1859 and 1866.

In considering the influence exerted by artillery in the war of 1859, it must be borne in mind that the whole of N. Italy from the Po is a genuine plain; the ground is marshy, the roads are raised on causeways, the whole face of the country is densely cultivated, the soil is rich, and the roads quickly become impassable, hence the action of cavalry and artillery is alike incommoded.

The French artillery was organized in batteries of 6 guns each, one per brigade; on the whole say 3 guns per 2000 men. The entire force of the arm was 288 guns, 18 guns were attached as a reserve to each corps (equal to 3 divisions of infantry and 12 squadrons of cavalry), and a general officer commanded the artillery on the staff of every corps. The gun itself was a rifled 4-pr. ranging about 3000 yards.

The Piedmontese adopted the arrangement of eight guns per battery, two being howitzers, about two guns per 1000 men. Two batteries were allowed per division, equal eight battalions and four squadrons.

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* O.S. Committee Extracts, Part 1. Vol. VI. p. 104.

† Some notes on Field Artillery. Campaigns 1859 and 1866. By an Officer, R.A.

The Austrian battery organization was the same as that of the Piedmontese; one battery accompanied each infantry brigade of five battalions; two such brigades and four squadrons composed a division, two such divisions with reserve cavalry composed a *corps d'armée*, to which forty reserve guns were attached, total amounting to near 1000 guns.

In the combats of Montebello and Palestro (19th and 30th May, 1859) artillery did not take a very prominent part, but on the former occasion an instance occurred of an Austrian battery protecting its guns by a thin breastwork, an arrangement not difficult to carry out by sinking a trench in front of a gun, using the earth as an epaulment and digging small ditches on each side of the gun into which gunners can if necessary quickly jump; such an arrangement has special advantages behind the edge of a hill, as the gun can in this manner be brought nearer the ridge.

On the 30th May the village of Vinzaglio sustained a cannonade from the Sardinian artillery without suffering much damage; a result which accords with the opinion that villages can be held against modern artillery unless set on fire by shells.

Magenta was fought, June 4, and up to, and including this action we find no overwhelming superiority consequent on and attesting the power of rifled artillery; this may have been partly due to unsuitableness of ground, and also to a failure in the action of fuzes.

But on June 24th was fought the great battle of Solferino, 300,000 men were engaged in the strife, and three crowned heads were present on the field; nor were the military features of the ground unworthy of the hosts who then went forth to the battle. There was alike cover for skirmishers and room for large deployments, communications were preserved by good roads, and gentle undulations afforded favourable sites for artillery.

Two noteworthy examples of the use of the arm occurred during the day. The Austrian gunners opened a fire upon a French deployment destined against Solferino and Cavriana; to this the French directly reply, and bring up a mass of cavalry and horse artillery, the latter supporting the cannonade of the twenty-four guns originally in action; a complete success is gained crowned by the action of the cavalry.

In this instance the enemy's artillery sought to oppose the progress of the French attack. The supporting guns were consequently employed in silencing the enemy's artillery. Here also we can observe the utility of the combination of cavalry and artillery which we are taught to expect more frequently on modern battle fields.

On the allied right lay the plain of Medole, very favourable to the combat of cavalry and artillery. At this point the Austrians sought to penetrate into an interval which had been left between the French divisions, but here, though the conflict raged for six hours, the combined fire of forty-two guns nullified the project; the incontestable superiority of the French rifled gun was thus shown on the first occasion which really afforded a means of comparison.

The immense power of these artillery masses can hardly be over-estimated; instances of such employment of the arm must occur to every one acquainted with the conflicts of modern warfare. In June 1862 at Malvern Hill the army of McClellan is said to have been saved from utter destruction by a mass of sixty guns, which being posted favourably in his centre, poured dismay and death into the columns of the Confederacy; and in reviewing the arrangements preceding the battle of Fredricksburg we observe that 250 guns, the bulk of the Southern artillery, were concentrated in enormous batteries on the right centre, and left of the line.*

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* Von Borcke's *Memoirs of Confederate War*, Vol. I. p. 71, Vol. II. p. 97.

It is no object of the writer of these notes to follow the progress of this use of field artillery from the time when mobility was first given to it, it is possible to arrive at one conclusion only from an examination of the varied instances when artillery has thus been employed on a large scale—how vast is the power of such batteries at every period of the progress of an action.*

The altered nature of the country gave to the artillery arm a vastly increased import in deciding the day at Solferino.

The French rifled guns are said to have played on the village of Solferino from a range of 2500 yards; it is probable that this range is a maximum, for there can be no utility in opening fire at distances beyond that which will permit of every projectile doing its work. The charge against artillery of opening fire too soon has been oft repeated, and the introduction of rifled guns caused very extravagant ideas to prevail as to the utility of the long ranges obtainable. The instructions of the Great Frederick are still applicable,—That it is at all times reprehensible and prejudicial for artillery to open fire so soon as the enemy can first be seen; exceptional cases may perhaps demand exceptional ranges, yet "all reports of the late war in Germany combine to prove practice at long ranges to be very doubtful in effect."†

1866. The Prussian army is composed of nine corps; the organization aims at producing from each corps a complete little army in itself. Each corps is composed of two divisions infantry, one division cavalry, and one regiment, equal sixteen batteries, equal ninety-six guns field artillery, with reserve artillery. In peace there are only four guns per battery, and pole draught is adopted. Total amount Prussian field artillery—162 batteries, 864 guns, rifled 4 and 6-prs. and smooth-bore 12-prs.‡ The guns are steel breech-loaders, the 6-pr. (Wahrendorff) is a position gun. The carriages are of wood. This light gun ranged further than the Austrian gun.

The reserve ammunition wagons in the field were kept quite separate from the batteries, the officers of which were able to attend to their proper duties free from the care of the distribution of ammunition to other arms.

The Austrian field artillery was muzzle-loading, 4-prs. and 8-prs., the guns and carriages lighter than those of the Prussians; the latter service carry a man on each axletree arm, a practice which though inconvenient enables them with the assistance of three men on the limbers to bring a gun quickly into action.§ The Austrians convey their extra men on a kind of saddle on the trail, two on the saddle of an 8-pr., one on that of a 4-pr.

The Austrian heavy field batteries then were composed of 8-pr. muzzle-loading rifled guns, their light batteries of 4-pr. muzzle-loading rifled guns.

The Austrian battery is of eight guns (280 rounds per gun), four 4-pr. batteries accompanied a *corps d'armée* of four infantry brigades and four squadrons cavalry. There were 108 batteries with the nine brigades of artillery.

Bavarian artillery.....	96 guns, rifled and smooth bore.
Saxon do	70 guns, rifled 6-prs. and 12-prs.
Hesse Darmstadt do	24 guns, rifled and smooth-bore 6-prs. and 12-prs.
Nassau do	16 guns, eight rifled.
Italy do	480 guns, rifled 8-prs. and 10-prs., in five regiments of 16 batteries, and 2 depot batteries.

June 26. The first army met and defeated Austrians at Liebenau; here smart cannonading occurred, but the Austrian guns were silenced. Their practice was very poor, the shells often penetrating into the earth without bursting.‖ A regiment of red hussars being exposed to a heavy fire, some fifty shells struck the ground around them, yet not a man of them was injured.

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* See Taubert, *Maxwell's Translation*, p. 200.
† Brackenbury, *European Armaments*, p. 52.
‡ I believe that now all the Prussian field guns are rifled.
§ Col. Reilly's Memo., p. 79. ‖ Hozier, Vol. I. p. 219.

June 28, at Münchengratz occurred an instance of that gross error so condemned by Frederick the Great of placing guns on the highest points on the field to obtain a greater range.* "The king called this a pernicious prejudice, since it was not length of range, but its closeness to the ground which produced a maximum effect: whence too it arose, that the shot in loose ground stuck fast, and in firm ground ricocheted over the lines of enemies troops." Thus the shells from four Austrian guns on the Mushey Berg hill instead of bursting among the troops went straight into the ground, and four Prussian batteries did but little execution against them, being misled by their height above the plain.†

On June 28, the Austrian General Gallenz, finding his right wing threatened, desires to change his front and uses his guns to cover the movement; twenty-four guns were deployed ere the Prussian advance came up, and the position was eventually stormed; though the Prussians had been for some time exposed to a very heavy artillery fire. It is said however that many of the Austrian projectiles did not burst, and that though the Austrians shot well early in an action, yet they were very apt to shoot too far, and that the longer an action lasted, the worse they aimed.‡

At Nachod, June 27, the General Commanding the Prussian advance, suddenly finding himself exposed to a heavy fire from Austrian guns, with the view of sheltering his infantry threw them into a wood, where they maintained themselves despite a shower of shell which burst around them—*Cf.* the result at Gettysburg, where it was said that the fire of shell against troops under cover in woods was not very fatal.

July 3, 1866, was fought the battle of Königgrätz; here it is a matter of surprise that more execution was not caused by the fire of so many rifled guns (600 Austrian, 816 Prussian). Some of the Austrian batteries fired away all their ammunition early in the day, and the Prussian shrapnel was a failure throughout the war, for they used percussion fuzes, which led to irregular bursting.§

The scene of this conflict embraced several villages characterised by fine wood cottages surrounded by orchards, when the Prussian guns were turned on these they caused much havoc.

The Austrian front was covered by the Bistritz, a marshy stream; the ground was known and prepared beforehand, the guns were favourably posted to pour a heavy fire on the Prussian advance, and the ranges were indicated by poles &c., somewhat after the Russian fashion at Alma; this position on the Bistritz was the Austrian first line, and this they were compelled to yield. In the fight which ensued an Austrian battery fired through a wood at the Prussians advancing to storm it; the combined effect of the fragments of shell and of the splinters torn off by them resulted in the failure of every attempt to storm the battery.

In the retreat which ensued the Austrians were indebted to their artillery who (though most of their position guns had been captured) came into action on every crest to gain time for the infantry to get away. The Austrians lost 174 guns.

At Tobitschau, 15 July, we meet with a remarkable instance of a quick advance of cavalry paralyzing the power to lay guns to suit the rapidly changing ranges. Two squadrons of cuirassiers are hurled full against the front of an Austrian battery, the ground over which they passed was undulating, their speed high. Twelve men and eight horses were lost, eighteen guns and 168 horses were won.

In concluding these brief notes I would quote from memory a remark of Okovneff on the subject of concentration of batteries in action, "Whatever," he says, "be the calibre of field artillery, to produce great results with it, it must be massed. The fire of three guns against an infantry battalion is of little use, whereas were two batteries deployed against it, it must retire."

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* Taubert, p. 51.
† Hozier, Vol. I. p. 229.
‡ Col. Reilly's Memo. p. 88.
§ Brackenbury, *Armaments of Europe*, p. 60.

SHORT NOTES ON PROFESSIONAL SUBJECTS,

1869.

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60. TRIAL OF IMPROVED CHASSEPÔT'S, FIRED IN COMPARISON WITH THE MARTINI-HENRY ARM FOR ACCURACY AT 500 yds. RANGE:—

An unofficial trial of the Chassepôt, in comparison with the Martini-Henry rifle, has recently been made at the Proof Butt, Woolwich, by the Sub-Committee on Small Arms, with very satisfactory results.

Captain Simon, of the French Artillery, submitted for trial three improved Chassepôt's, and they were fired in comparison with the Martini-Henry arm for accuracy at 500 yards range.

The results of the shooting were as follows:—

Arm.	By whom fired.	Mean deviation of 20 shots.
		ft.
Martini-Henry, No. 3.	Serjeant Bott, R.M., kneeling position.	1·03
Chassepôt, No. 1.	Captain Simon, from shoulder rest.	2·78
Martini-Henry, No. 3.	" " "	0·97
Chassepôt, No. 1.	Serjeant Bott, R.M., kneeling position.	3·02
Martini-Henry, No. 1.	Edward Ross, Esq., sitting position.	0·96
Chassepôt, No. 2.	Captain Simon, from shoulder rest.	2·78
Martini-Henry, No. 1.	" " "	1·62
Chassepôt, No. 2.	Captain Mackinnon, sitting position.	2·38

Thus the accuracy of the Martini-Henry arm far excelled the Chassepôt.

Heights of trajectories of the two arms at 500 yards. Chassepôt 10 feet at its highest point. Martini-Henry 8 ft. 2 in.

In simplicity of manipulation the latter arm is also superior.

20 rounds were fired for rapidity, with the following result:—

Chassepôt.....	1 minute 42 seconds.
Martini-Henry	" 48 "

The manipulation of the Chassepôt was found very fatiguing. In simplicity and strength of construction, the advantage appears to be with the Martini-Henry arm.

Captain Simon informed Sub-Committee that the French soldier carries two spare spiral springs, two needles, and one India-rubber washer, to replace any breakages or injury of these parts.

There were no miss-fires with the Chassepôt out of the few rounds fired by the Sub-Committee, but after 10 rounds it became difficult to push home the cartridge, owing to the clogging of the chamber, the cartridges had to be forced in by blows,

sometimes frequently repeated. In the event of a miss-fire, there is no way of withdrawing the cartridge, except by using the ramrod.

The ammunition of the Martini-Henry arm is slightly more bulky than that of the Chassepôt.

The weight of the 90 rounds is:—

	lbs.	oz.
Chassepôt	6	9
Martini-Henry	9	5

The bullet of the latter, however, weighing 480 grains, against 380 the weight of the Chassepôt bullet. The cost of the cartridges is believed to be about equal.

The only advantage in favour of the Chassepôt is in the lightness of its ammunition. This is counterbalanced by the following points, which are in favour of the Martini-Henry arm:—

Increased strength and safety of ammunition.	Higher penetrative power.
Greater accuracy.	Greater safety, strength and simplicity of construction.
Longer range.	Increased rapidity of fire.
Flatter trajectory.	

61. EXPERIMENTS TO ASCERTAIN THE PENETRATION OF SMALL ARM BULLETS INTO VARIOUS SUBSTANCES:—

The following is an abstract of the results obtained up to 1st March, 1869, from a series of experiments made at Woolwich, to ascertain the penetration of small arm rifle bullets into various substances.

The small arms used during the experiments were as follows:—

(1) Henry B.L. rifle, calibre 0·45 in.; Boxer cartridge; Henry solid bullet of 480 grains hardened with $\frac{1}{13}$ of tin. Charge 85 grains. Curtis and Harvey powder, No. 6.

(2) Snider small bore B.L. rifle, calibre 0·5 in.; Boxer cartridge; Boxer bullet, with hollow head and expanding base, 440 grains. Charge 80 grains. Rifle F.G. powder.

(3) Snider service B.L. (long) rifle, calibre 0·577 in.; Boxer cartridge; Boxer bullet with wood plug in apex and expanding base, 480 grains. Charge 70 grains. Rifle F.G. powder.

(4) Enfield muzzle-loading long rifle, calibre 0·577 in.; service cartridge. Solid bullet with expanding base, 530 grains. Charge 70 grains. Rifle F.G. powder.

The line of fire was in all cases direct.

Wrought-iron plates, 6 ft. × 2 ft., secured to a wooden frame, but unbacked. All the rifles used.

No. 1, Birmingham gauge, 0·312 inch in thickness:—

At 100 yards, quite proof against all the arms.
" 50 yards, Henry nearly through; proof against the others.
" 25 yards, Henry through, 3 times out of 4; proof against the others.

No. 3 gauge, 0·261 inch:—

At 350 yards, proof against all.
" 300 yards, Henry nearly through; proof against others.
" 200 yards, Henry through; proof against others.
" 100 yards, all through, except service Snider.
" 75 yards, service Snider through.

No. 5 gauge, 0·217 inch:—

At 300 yards, Henry through, proof against others.
" 200 yards, all through except service Snider.
" 100 yards, service Snider through.

No. 7 gauge, 0·187 inch:—

At 300 yards, all through except service Snider.
" 200 yards, service Snider through.

No. 11 gauge, 0·125 inch. Two plates of this gauge placed at $1\frac{1}{2}$ inches apart:—

At 500 yards, Henry through both.
" 300 yards, proof against all except Henry; bullets passed through front plate, but were stopped by one in rear.

Steel plates supplied by Mr Deane, 6 ft. × 2 ft., secured as above. All the rifles used.

No. 5 gauge, 0·217 inch:—

At 10 yards, proof against all.

No. 7 gauge, 0·187 inch:—

At 50 yards, proof against all.
" 25 yards, " except Henry.

No. 9 gauge, 0·158 inch:—

At 200 yards, proof against all.
" 100 yards, " except Henry.
" 50 yards, " " and Snider small bore (0·5 inch).

No. 11 gauge, 0·125 inch:—

At 300 yards, proof against all.
" 200 yards, " except Henry.
" 100 yards, " " and Snider small bore (0·5 inch).
" 50 yards, all through except service Snider.

Rifles.—Henry, Snider service (0·577 in.), and Snider small bore (0·5 in.).

At planks of timber, green oak, 2 planks one on the other, each 3 inches thick; total thickness 6 inches.

Henry passed through the first plank and lodged in second.
Others, stuck in first plank, bulging it at back, the Snider small bore giving a greater penetration than the service arm.

Dry fir,—2 planks as above.

Henry through both.
Others, through one and lodged in two, the Snider small bore giving the deepest penetration.

At 100 yards, 3 planks as above:—

Henry through all.

4 planks as above (3 dry, 1 green):—

Henry through all.

Gabions.—Ordinary, filled with stiff clay taken from the Proof Butt, Royal Arsenal.

Rifles used.—Henry, Snider service (0·577 *in.*), *and Snider small bore* (0·5 *in.*).

At 50 yards, proof against all.
" 25 yards, " except Henry, which sometimes passed through.
" 10 yards, " " " "

Jones's iron gabion, filled as above.

At 10 yards, proof against all.

Sap roller.—Length 7 *ft., total diameter* 4 *ft., thickness* 11½ *ins.*

At 50 yards, proof against all.
" 25 yards, " except Henry occasionally.
" 10 yards, " " "

A sand bag, containing a bushel of sand, about 12 *ins. thick, rifles as before.*

Proof against all at 10 yards, except the Henry, which occasionally passed through.

Parapet of stiff earth, 3 *ft. thick, on superior slope.*

Proof against all at 10 yards. The Henry penetrated 21 inches.

A rope mantelet consisting of 4 *thicknesses of* 3*-inch rope, rifles as before.*

At 400 yards, proof against all.
" 350 yards, Henry sometimes through.
" 300 yards, Henry through, proof against the others.
" 50 yards, Snider small bore through in *pieces*, proof against service Snider.

Complete perforation depended in some measure on the particular part of the mantelet struck. Thus, when hit in the interstices between the ropes the penetration was greater; the mantelet, however, was not considered satisfactory, and a new one was subsequently demanded.

The following conclusions may, in Captain Noble's opinion, be drawn from the results of the experiments as far as they have gone:—

(1) Steel plates offer a much greater resistance than those of wrought-iron.

(2) A steel plate of No. 5, Birmingham gauge, 0·217 inch in thickness, is proof at 10 yards against any small arm bullet likely to be used for sometime to come.

(3) A wrought-iron plate of 0·312 inch thickness is not proof against the Henry bullet at 25 yards.

(4) A Jones's gabion filled with stiff earth is proof against any small arm bullet at 10 yards.

(5) A slight breastwork of filled sandbags or loose earth is proof against all small arms.

(6) The rope mantelet used gave unsatisfactory results.

(7) Two 3-inch planks of green oak are proof against any small arm bullet at 50 yards.

(8) The Henry bullet will pass through 12 ins. of fir planks at 100 yards.

62. Mallet's 36-inch Mortar:—

In October last, it was found that the wooden bed and platform of the Mallet mortar mounted in the Marshes at Woolwich was in so decayed a condition that fears were entertained lest the mortar should fall.

As it would have entailed considerable expense to dismount the mortar, and then to remount it on a new bed and platform, it was decided to destroy the decayed bed by means of a small charge of gun-cotton, and thus allow the mortar to subside on to the ground.

This operation was successfully carried out by Mr Abel, Chemist to the War Department, at a cost of 12s. 10d., and the following report of the experiment may probably interest some of the members of the R.A.I. The weight of the mortar is 42 tons:—

The bed, which was of elm, was very rotten throughout, and therefore in the condition most unfavourable to the full exercise of the action of gun-cotton. Five holes 1·5 inch in diameter were bored at a somewhat obtuse angle into the front face of the bed; the centre one was 2 ft. deep, and the four others 18 ins. Two lateral horizontal holes were also bored into each side of the bed at a little distance beneath the trunnions—the diameter of these holes was also 1·5 in. and 2 ft. 6 in. deep.

The central (2 ft.) hole in the front face was charged with compressed gun-cotton pellets, 1·25 inches in diameter, weighing 6·5 oz., and filling a length of about 9 inches of the hole. The other four holes in this face were each charged with 4 oz. of gun-cotton pellets. The lateral holes received each a charge of 8 oz. The total quantity of gun-cotton in the nine holes amounted therefore to 3 lbs. 6·5 oz. Electric detonating fuzes were placed upon the upper ends of the charges, and the holes were loosely plugged with wood borings to keep the fuzes in position.

The nine charges were then exploded simultaneously, whereupon the mortar swayed forwards and appeared about to fall, but although the entire rear part of the bed was at once permanently raised from the ground by the great preponderance in front, the mortar came to rest almost directly and remained firmly standing.

The front face of the mortar bed had been to a great extent blown away and the wood composing it, and the portion of the bed beneath the trunnion block was completely disintegrated, but the enormous mass of metal resting upon this point caused the trunnion block to sink into and become firmly imbedded in the broken up wood, before the retaining power of the rear-fastening was overcome by the tilting forwards of the mortar. The latter seemed, therefore, to remain almost as firmly fixed as it originally was, but it appeared as if the equilibrium of the mass were in great measure maintained by the rear connexion of the mortar with the bed, through the agency of the keep-screw and bolt above described. It consequently was considered possible that, if this bolt could be broken, the relief of the mortar from its rear fastening might cause it to fall over. A disc of compressed gun-cotton, *quite freely exposed*, weighing 1 lb., with an electric detonating fuze attached, was therefore tied to the lower side of the iron joint, which connected the keep screw with the bolt. Its explosion, which was attended by a report like that produced by a heavy gun, snapped the iron joint in two, and also broke the wrought-iron bolt just where it entered the bed, so that it fell away from its fastening at the base of the bed. The mortar again moved forwards slightly, and the rear end of the bed was lifted still further, but the mass continued standing.

It was now evident that the mortar was prevented from falling by the very firm manner in which its trunnion block had become imbedded in the soft self-padding *debris* of rotten wood, which was greatly aided, in the support it afforded, by the bolts on either side of each trunnion, which passed through the entire depth (3 ft.) of the bed at that part, and were nutted against iron plates let into its base. One trunnion had sunk considerably deeper into the wood than the other, and advantage was taken of cavities produced by the first explosion in that side of the bed, close to the bolts described, to place a disc of gun-cotton, weighing 1 lb., immediately under each side of this trunnion and close to each bolt. It was hoped that the simultaneous explosion of these two discs would lift the trunnion, and also destroy the support afforded by the bolts, either by snapping or drawing them. At the same time, with the view of aiding the effect of this explosion by simultaneously bringing an impetus to bear upon the rear portion of the mass, a 1 lb. disc of gun-cotton was inserted between the breech of the mortar and the cavity in the bed originally intended to receive it, but from which it had parted by the forward tilting of the mortar. The result of the simultaneous explosion of these three charges showed that a correct estimate had been formed of their effect. The mortar swayed for an instant or two and then fell slowly forward upon its muzzle.

The great feature of novelty connected with this operation, was the accomplishment of great mechanical work by perfectly unconfined gun-cotton, the force of which was instantaneously developed through the agency of a small initiative detonation.

The total amount of gun-cotton used in the operation was 7 lbs. 6·5 oz., the cost of which, at the present retail price, was 12s. 10d. There is little doubt that the 1 lb. charge of gun-cotton expended upon the fracture of the rear bolt might have been saved, if, after the first explosion, recourse had been at once had to the plan of relieving the trunnions, and at the same time of applying a lifting force to the rear of the mass.

63. "In Memoriam" of the late Lieut. A. E. Baines, 10th Brigade, R.A.

On the 14th October 1866, a terrific conflagration took place at Quebec, Canada, resulting in the destruction of 2500 houses.

During its fury, explosions were heard in all directions, and whilst a number of artillerymen were engaged in blowing up several houses, Lieut. Baines placed a keg of powder inside a brick building which he had decided upon blowing up, in order to save an institution called the "General Hospital Convent," connected with the latter by a wooden shed. Immediately on Lieut. Baines firing the fuze, he observed a shower of burning wood falling down the chimney of the house; his first impulse was to make his escape any way, but before he could do so, the charge was ignited by the burning timbers falling on it, and the walls of the house fell on him, crushing him frightfully.

Lieut. Baines was immediately removed to the General Hospital Convent, where the Sisters of Mercy kept watch night and day by the bed-side of the wounded officer. Hopes were entertained of his recovery, but after 13 days of intense suffering he expired in the arms of some of the officers of his brigade.

The burns which he suffered were comparatively slight, but the injuries he received by the wall falling on him was so great that the Medical officers said that even if tetanus (the immediate cause of his death) had not intervened he could not have lived a year.

Lieut. Baines was much esteemed by his brother officers and much loved by the soldiers; one of these last said a few minutes after the accident, "I would have given my life to save my officer."

During the whole of his illness he displayed courage, patience, and resignation. When hopes of living were very faint, he expressed his submission to the Divine Will, and said, "If I die, I die in the performance of my duty, and I thank God that I should so die."

The sorrow which was felt for the melancholy death of Lieut. Baines evoked deep expressions of sympathy from the whole community. An extract from the "Quebec Mercury" will serve as an example of the general feeling, viz.— "The calamity of the 14th October has culminated in one of those episodes which by their grandeur and fatality evoke the extreme chords of human sympathy. The mournful death of Lieut. Baines, while it fills us with indescribable awe and the lowliest submission to the fiat of an all-wise Providence, excites in the soul of every good citizen the loftiest admiration for the grand heroism which led through danger and suffering to death."

The following is an extract from a letter written by Lieut.-Colonel McCrea, Lieut. Baines immediate Commanding Officer:—

27th October.

"I have just returned from the Hospital and brought under God's will the sad news that my deeply to be regretted officer died at 12 o'clock, released from great suffering by thus passing quietly away through the gate which we must all follow him. No pen can possibly express what we all here feel and how deeply we deplore his loss."

As a mark of the deep sense entertained of Lieut. Baines's valuable services during this awful fire, and sorrow for his loss, the Mayor of Quebec, Joseph Canchon, Esq., by public proclamation, called upon the citizens generally to attend his funeral. This request was heartily responded to.

The funeral was in every respect a public one, and was attended by the staff of the Governor-General, the Premier and Ministers of the Government, Members of Parliament, Mayor and Corporation of Quebec, and many thousands of the citizens, in addition to the Commandant and all the officers of the Garrison, and also of the Royal Navy. The shops were everywhere closed, and all the vessels in the harbour had their flags half-mast high.

Lieut. Baines met a glorious death, for he gave his life to save others, and this was the feeling amongst all the residents of Quebec at the time. The General Hospital Convent, which was preserved from destruction by Lieut. Baines, contained 300 inmates, 150 of whom were infirm and helpless.

A monument has been erected by the citizens of Quebec to Lieut. Baines' memory in Mount Hermon Cemetery, and a sum of money was subscribed by them and remitted to his bereaved mother for the purpose of placing a memorial to her son in his parish church, or wherever she might think desirable. Mrs Baines made choice of a pulpit, which has been erected in Stockwell church, near Brixton, Surrey, where Lieut. Baines used to attend.

Photographs of both these memorials are deposited in the R.A. Institution.

The Officers of Lieut. Baines' Brigade have also put up a tablet, in the form of a cross, to his memory in the cathedral at Quebec.

64. On Lysons' Improved Signals for Rifle Practice:*—

The stimulus given to rifle practice in this country by the Wimbledon meetings, by the regulations in the Volunteer Force with reference to efficients, and by the rigorous enforcement of it in the Regular Army in all its details, has succeeded in rendering a range as familiar an object in every town and village, as a cricket ground, or bowling-alley. While, however, the improvement in shooting has been continuous and marvellous, the apparatus for recording and conducting the practice has remained of the rudest description. Communication between the firing party and the butt is limited as a rule to the brief vocabulary of a couple of buglers and a red flag; and the wind renders this arrangement uncertain, and often useless. At rifle practice, uncertainty means danger; and that there are not more accidents is not due to the existing system, but in spite of it. A bugle is of no use whatever at long ranges when the wind is blowing across the range, or even at comparatively short ranges when the force of the wind is great, as it is on river-side ranges and breezy downs; and should the wind be blowing up or down the range, the red flag, blown end on, is frequently invisible, more especially in the evenings, when most of our volunteer class shooting is carried on. Should it be necessary to communicate with the marker, the tedious method has to be employed of sending a man to him, thus delaying the practice, and unsteadying the man for shooting, should the messenger have belonged to the firing party. Tedious, however, as this method is, it is a very general one; for buglers are rarely to be secured on country ranges. What is the general result? Rather than delay the practice, the men become careless as to many points which they should learn from the marker, and which would correct their firing; and their shooting is inferior to what it might easily become. A *miss* is only known as such by the absence of a chronicling flag from the butt, and no information is given to the unhappy marksman, as to whether he is firing high or low, to the right, or to the left.

To remedy all these defects, a new system of signalling has been invented by Captain and Adjutant Lysons, of the 1st Administrative Battalion, Aberdeenshire Rifle Volunteers, which the writer of this paper has seen in operation. Its success has been unequivocal; its simplicity is great; it is not liable to derangement; and at the longest ranges it can be worked by the rifleman and marker alone with the greatest ease. With it no bugles are required; the wind cannot affect it; no running up and down the range is necessary; communication with the marker is instant, and conversation can be maintained with ease between him and the firing. The cost of the whole apparatus is small; it is perfectly durable, and could be left permanently standing on a range, so that a couple of men could carry on practice without any assistance, one firing, the other at the butt, and do as much in one hour, as under the existing system can be done in three.

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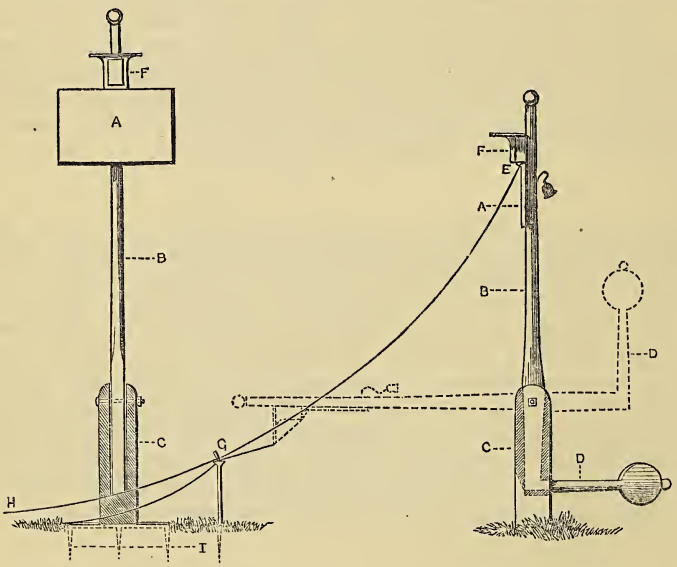
* By Captain and Adjutant F. Duncan, R.A., M.A., D.C.L., F.G.S., F.R.G.S.

The following are the general principles:—

Planted in the ground a little to the front of the butt, out of the line of fire, is a pole with a socket in which a lighter pole is swung, kept erect by means of weights, but easily pulled down into a horizontal position by a cord attached to the top, running along the range to the firing party. On this lighter pole, a red square is stretched, composed either of bunting or painted tin, perforated with holes, in case of wind. This red square is at right angles to the range, and can be seen at a very great distance. A small bell is attached to the pole, which rings when the firing party either pull down the pole or let it up again. The end of the cord is made fast, when the pole is pulled down into a horizontal position, to a small cleat provided for the purpose; and when in this position no red disc can be seen, and firing may be carried on. On letting go the running end of the cord, the weights bring the pole into a vertical position again; the red square is seen all over the range, and firing is suspended. An exactly similar pole is planted in the ground close to the firing party, and the running end of the cord is in the butt. Being very light, this pole is carried up and down the range by the firing party, to the various distances from which the shooting is to be carried on.

The following rude sketch will give an idea of the mechanical details of an invention which will probably soon be extensively used. Pending the introduction of further improvements, Captain Lysons has obtained provisional protection for his discovery, but he aims more at increased simplicity than at elaborate detail.



A, red square; either bunting in a frame, or painted tin, perforated so as to offer little resistance to the wind.

B, swinging pole.

C, stationary pole, which is planted in the ground by means of a forked foot, and can be carried to any part of the range, and planted in the ground by one man.

D, lever arm with 30 lbs. weight attached, to bring the swinging pole into a vertical position.

E, *G*, *H*, the cord by which the pole is pulled into a horizontal position.

F, lamp.

G, rod planted in the ground, by means of which the cord is guided.

I, forked foot, by which the standing pole is planted in the ground.

NOTE.—On a permanent range it would be well to pass the cords through small pulleys or rings, attached to posts at every fifty yards, which could also serve to mark the distances along the range. This would greatly diminish friction, and save the cord from being frayed or trod upon.

By the use of a small double roller kept at the butt, both cords can be drawn in together. Over rough ground, it took seven minutes to draw in two lengths of 800 yards. The roller, with the cord, is kept in the butt, and the whole of the pole apparatus can be taken to pieces, and packed in a box with ease.

Now let us see how it works. We suppose first that the firing has not commenced; both poles are erect, one facing the firing party, the other the target. The marker gets everything ready; and then by means of the running end of the cord at the butt, he pulls down the pole at the firing party in a horizontal position, and makes fast. The tinkling of the little bell alongside of them, calls the firing party's attention to the fact that the marker is ready; and they answer his signal by pulling down the pole at his end, and making fast. The firing now commences, the marker registering his "bull's eyes," "centres," and "outers," as at present. Perhaps, however, he is doubtful of some hit, and desires to inspect the target. He accordingly lets go his running end, up flies the pole at the firing party's elbows, and he remains in the butt until he sees his own pole fly up, in acknowledgment of his signal, when he goes out in perfect safety to make his inspection. Having done so, he returns to the butt, pulls down their pole, they pull down his, and the firing re-commences. So *vice versâ*. An anxious rifleman, who is missing the target at 900 yards, wishes to know where his shots are going, that he may alter his aim. Accordingly he lets go *his* running end; up flies the marker's pole; the marker shows that he is awake by letting up the pole at the other end, and awaits instructions. The rifleman then, according to a preconcerted code of signals, pulls down the marker's pole "once," "twice," or "thrice," and then leaves it erect. The marker understands "Mark the last shot," goes out, points with his small flag to the right or left of the target as the case may be, returns to his butt, pulls down the other pole; the rifleman pulls down his, and now, a wiser man, corrects his aim, and makes a bull's eye.

At a public exhibition of this invention of Captain Lysons, this last operation was performed in 45 seconds.

By preconcerted signals like this, any message may be sent. Once pulling down the pole might mean "Paint out;" twice "Increase the target for 800 yards;" thrice "Mark the last shot." In the same way, the marker by pulling down the pole at the firing end so many times, as agreed upon before the practice, can obtain any information he may want.

On account of the rigidity of the red square, no wind can blow it end on; nor dare any man fire a shot until the pole at his elbow is pulled down by the marker at the butt to show that he is ready. When we remember the numerous accidents that have occurred under the rude system of signalling, now in use, this total immunity from danger which the marker enjoys is the most important result of Captain Lysons' invention, and has struck every one, whether regular or volunteer, who has seen it at work. No excuse can be given now for not seeing the marker's danger flag, as it is *in the midst* of the firing party themselves, whether they are firing at 400 or 900 yards.

And to prove how accurately the poles are balanced, and yet with what ease they can be pulled down owing to the leverage given, which is presently to be described, the writer of this paper can state that at a distance of 800 yards, with the cord passing over a ploughed field, unsupported by rings or poles, he pulled the pole into a horizontal position with one hand; and that his letting go the running end, and the consequent springing of the pole into a vertical position were almost instantaneous.

It sometimes happens, more especially upon country ranges and among volunteers, that the firing is continued until it is so dark as to render a red flag, even at right angles to the range, not very distinguishable. To obviate a difficulty caused by a practice which is much to be deprecated, Captain Lysons has arranged to have a lamp with a powerful reflector hung above the red square, whose white light is visible at a great distance when the pole is erect, and yet by an ingenious arrangement is invisible when the pole is in a horizontal position.

65. Description of a method of taking heavy weights over broad and deep ditches.*

The undermentioned plan was adopted in May and June last for taking guns, carriages, and platforms across the ditch surrounding the Drop Redoubt at Dover, under the superintendance of this officer.

The guns (40-prs. of 32 cwt.) were taken from the redoubt across the ditch. From crest of exterior slope to edge of glacis 87 feet (this was the distance the weights travelled in the air).

The heaviest weight taken over (consisting of two dwarf traversing platforms lashed together) was about 67 cwt.

Sheers (*A*), length of each spar 36 feet. Gyn, common, 18 feet, used as sheers (*B*), three guys and capstan (*C*), were placed as shown in plan and elevation. (See also large sketch).

The triple blocks of two gyn tackles were connected with the heads of the gyn and sheers respectively. The running ends of the falls of both tackles were led by leading blocks (*x*) and (*y*) to the capstan, when both were coiled on the drum in such a way that when one was hauled in the other was paid out. (See Fig. 1).

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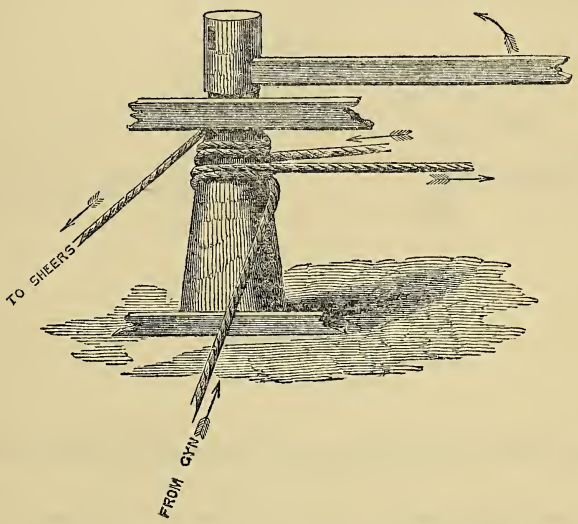
* By Lieut. G. Mackinlay, R.A.

The sheers and gyn were made as nearly upright as possible, the gun or other weight to be taken across the ditch was placed on the top of the superior slope, and the double blocks of both tackles were hooked to the gun-sling. Both tackles were then hauled in alternately, the gun moved along the slope, fell off it, and became suspended under the sheers.

The capstan was then manned, working both tackles at the same time and moving the ropes as shewn by the arrows in Fig. 1. The gun travelled across the ditch along the dotted line (theoretically part of an ellipse of which the foci were the heads of sheers and gyn).

Fig. 1.



The time taken by one gun in travelling from the outer side of the exterior* slope to the opposite side of the ditch (87 feet) was an hour. The time might have been much less had there been more men, but there was only one small relief to work the capstan.

This method admits of considerable modification. In some circumstances (with a narrow ditch or with a light weight) one sheers only would be necessary. On the other hand if the weight were very great it would be necessary to allow the weight to descend lower into the ditch than in the particular case described, but of course this proceeding involves more time and labour.

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* From top of scarp to top of counterscarp 50 ft. From feet of gyn to feet of sheers 80 ft.

The best method to adopt under any circumstances can easily be ascertained by estimating the strains on the various ropes and pickets and making dispositions to avoid giving too much strain to any part.*

On a subsequent occasion the triple blocks were attached to the moving weight; more power by the tackles was thus gained, and (more men being available) the capstan was not used, but the running end of the gyn tackle was hauled in by men, and the weight (a platform) was brought over in a very few minutes.

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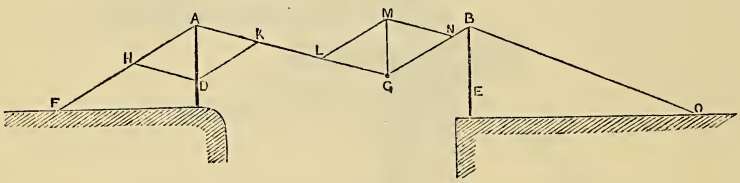
* Disregarding friction and the weight of the ropes the strain can easily be found as follows when the gun is in any position *G*. See fig. 2.

Fig. 2.



Let *AD*, *BE* represent sheers,

FA, *BO* back guys,

AG, *GB* tackles.

First, Through *G* draw *GM* vertically; make the length *GM* to represent the weight of the gun.

Through *M*, draw *ML*, *MN*, parallel to *BG*, *AG*, respectively. Then, lengths *GL*, *GN*, represent strains on tackles respectively.

Second, From *A* along *AG*, mark off *AK*, equal to *GL*.

Through *K* draw *KD* parallel to *FA* and through *D* draw *DH* parallel to *AG*.

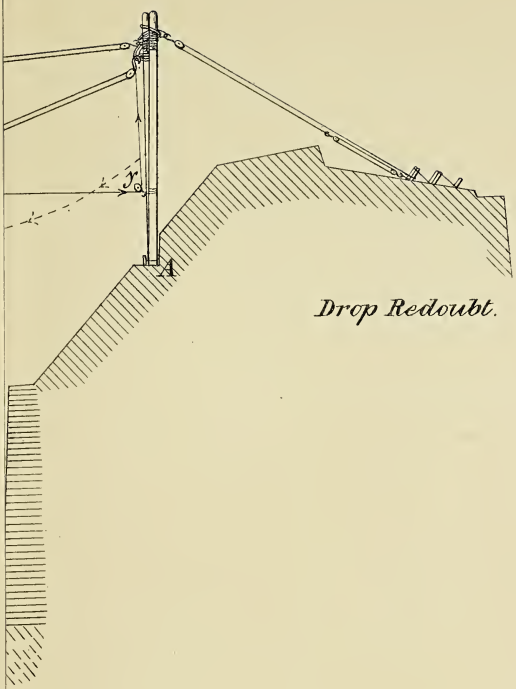
Then *AH* represents the strain on back guy and pickets, and *AD* the thrust on sheers.

In like manner the strain on the other back guy can be estimated.

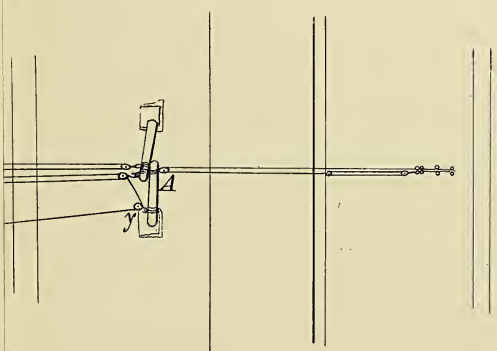
From this it is evident that the greater the angle *AGB* the greater will be the strains on all the ropes.

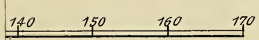
ERRATUM.

p. 60, four lines from bottom, *for* "14 lbs. charges," *read* "40 lbs. charges."



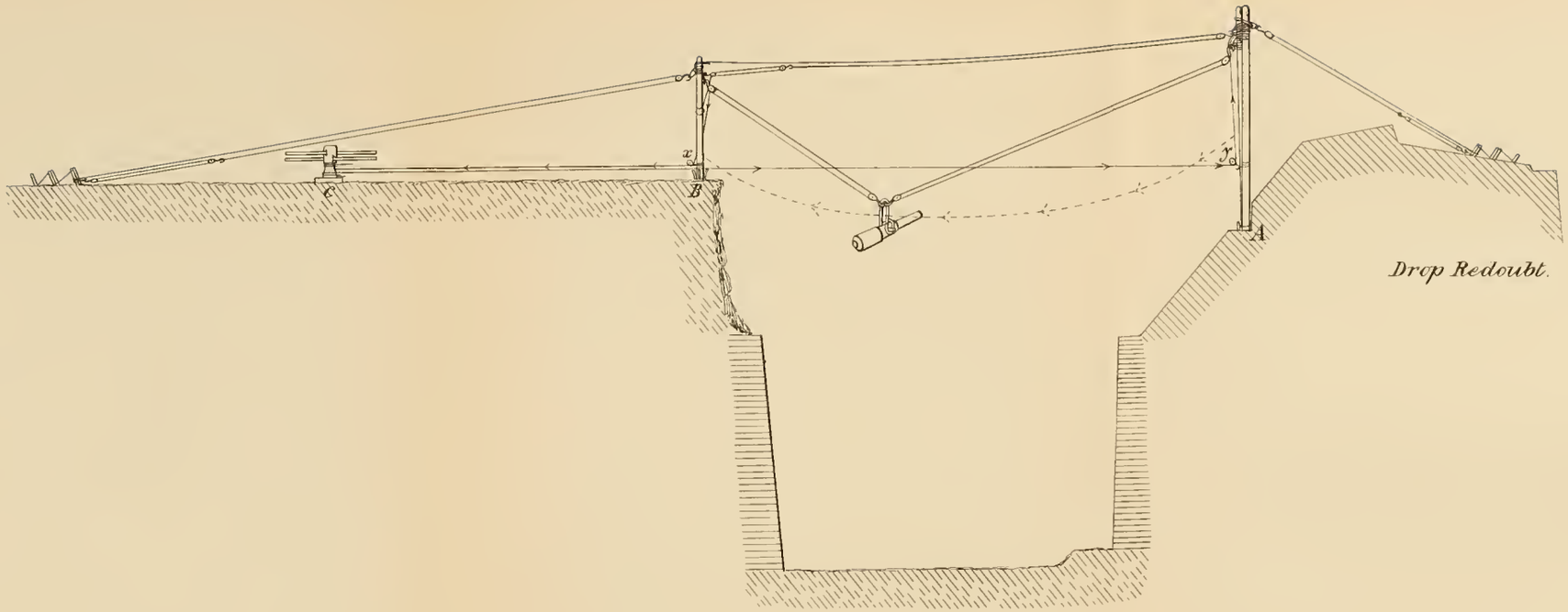
Drop Redoubt.





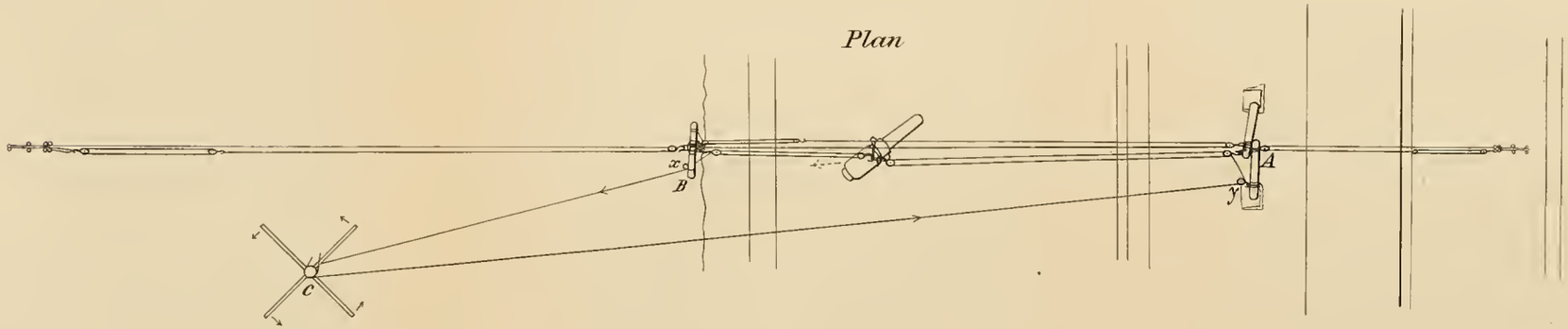
Lithographed at the Royal Artillery Institution

Elevation.

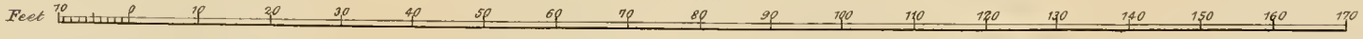


Drop Redoubt.

Plan



Scale



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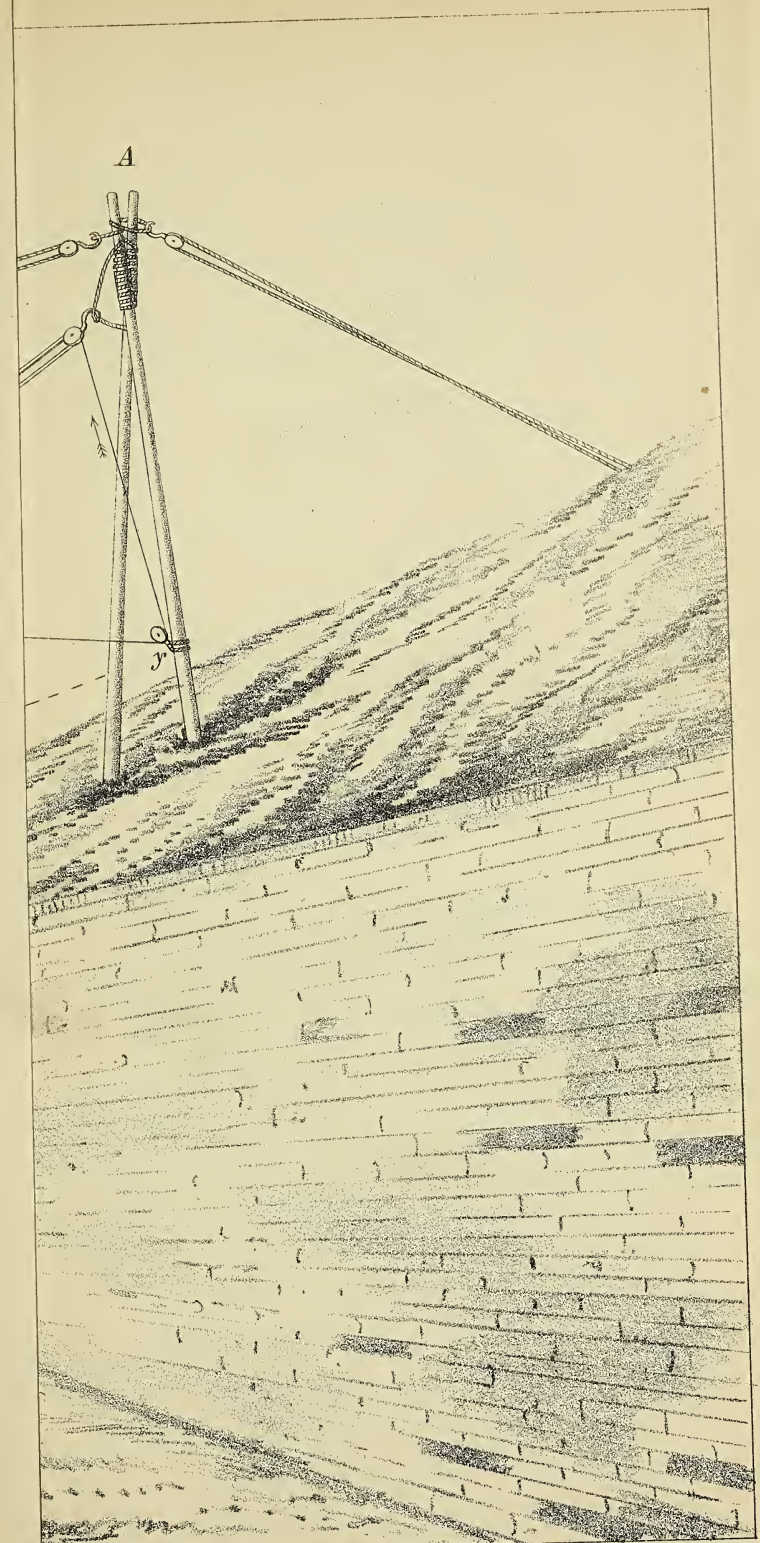
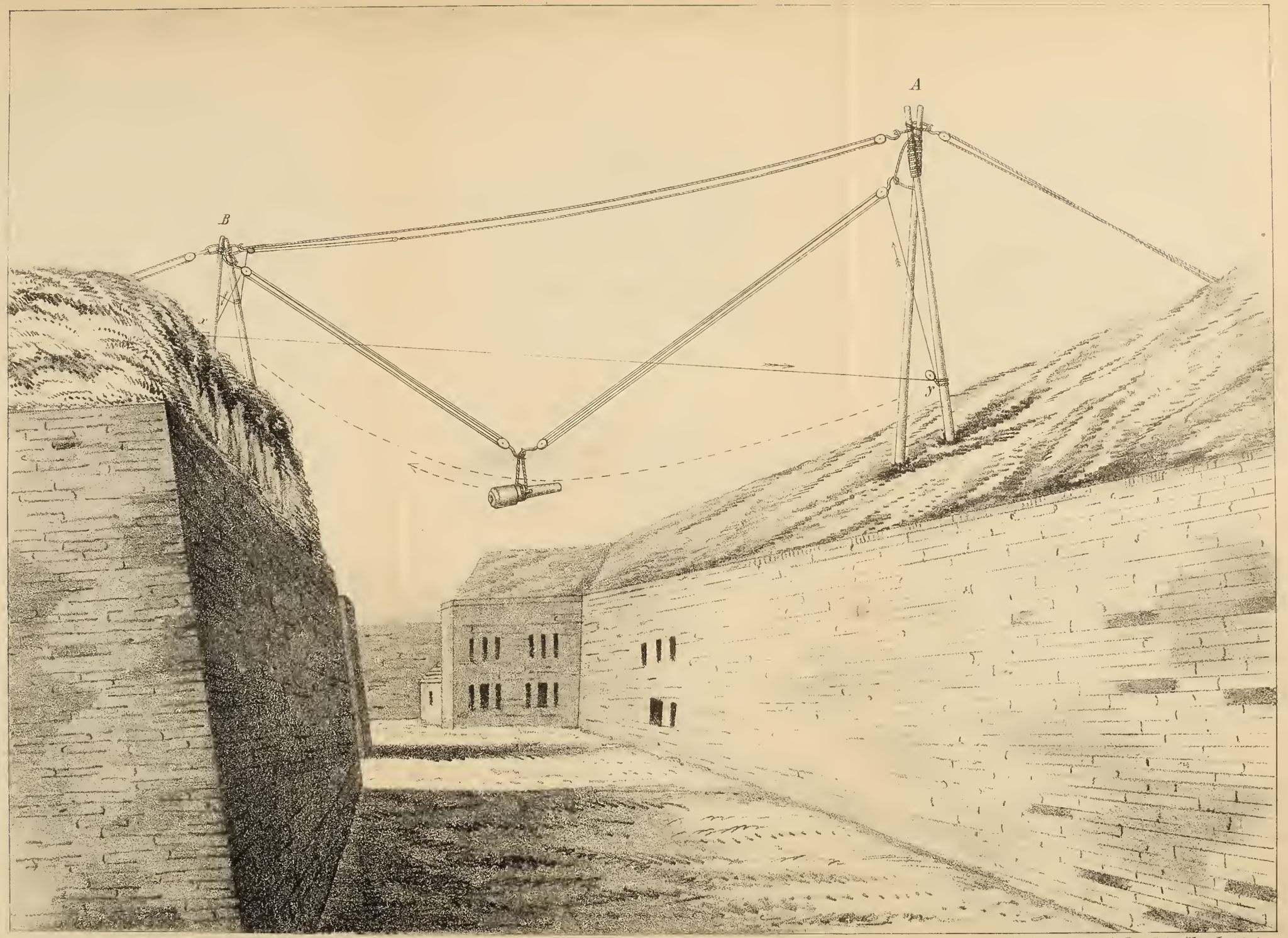


Lithographed at the Royal Artillery Institution



Lithographed at the Royal Artillery Institution

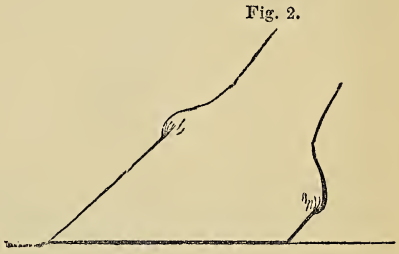
66. Hints on Shoeing Horses*.—The shape or form of a shoe has very little influence on the functions of a horse's foot, the object to be gained by any particular pattern being that it is light, will wear a month at least, not likely to be pulled off, and requiring few nails to retain it. But the methods of preparing the foot and applying the shoe as generally carried out, interfere greatly with the healthy state and functions of the foot.

In removing the old shoe prior to a horse being newly shod, each nail should be drawn by the pincers independently, and not the shoe torn off as is usually the case.

The shoe being removed, the smith satisfies himself as to the obliquity of the foot, which is readily done by allowing the horse to stand on a level floor, and himself retiring a few paces, so as to obtain a view of the angle formed by the front of the foot and the surface on which the foot stands. This angle should be about 50 degrees, as shown by Fig. 1.

Fig. 1.

Fig. 2.



If the obliquity is greater as shown by Fig. 2, in other words the angle less than 50 degrees, a portion of the crust round the toe only and on the ground surface should be removed; should the obliquity be correct, and there is a superabundance of crust, it must be removed by rasping from toe to heel; these operations are represented by Figs. 3 and 4, the dotted lines indicating the portions of crust to be removed.

Fig. 3.

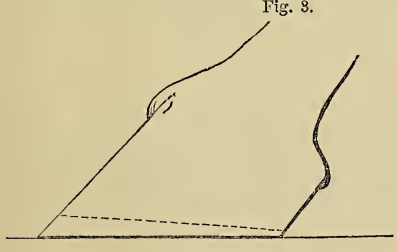
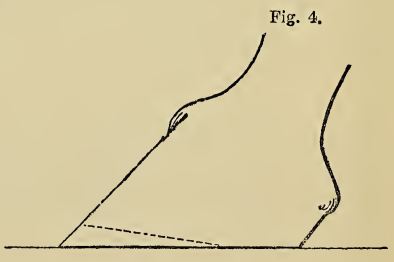


Fig. 4.



When too great an obliquity exists, it is owing to the heels having been pared or rasped more than the toe.

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* The subject of a letter from Staff Veterinary Surgeon Thacker to Captain A. H. W. Williams, R. H. Artillery.

Very few horses require any of the crust removing, beyond what is done in fitting the shoe; the more horn there is below the sensitive parts, the less mischief nails do, as shown by the following Figs. 5 and 6 :—

Fig. 5.

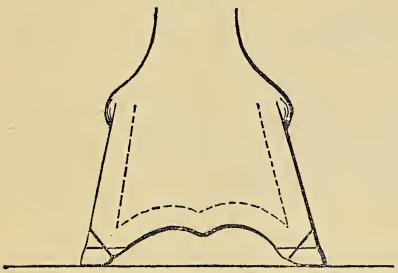
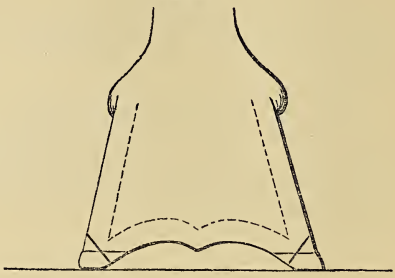


Fig. 6.



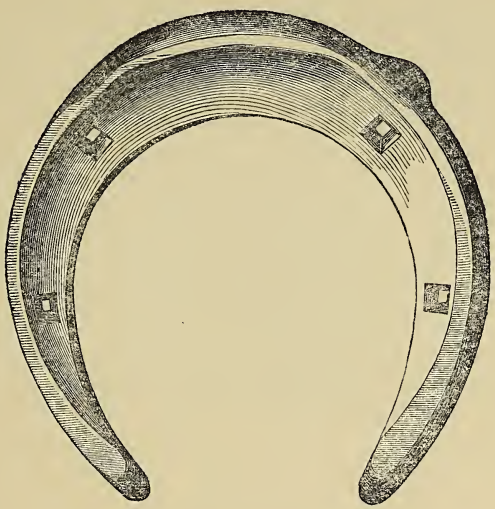
The dotted lines represent the sensitive laminæ; by leaving sufficient horn the nails are far removed from this extremely delicate membrane. It is not absolutely necessary for a nail to penetrate the sensitive laminæ to cause mischief, for if the nail approaches it, the horn which becomes displaced presses upon the laminæ and causes considerable pain on a membrane so highly sensitive.

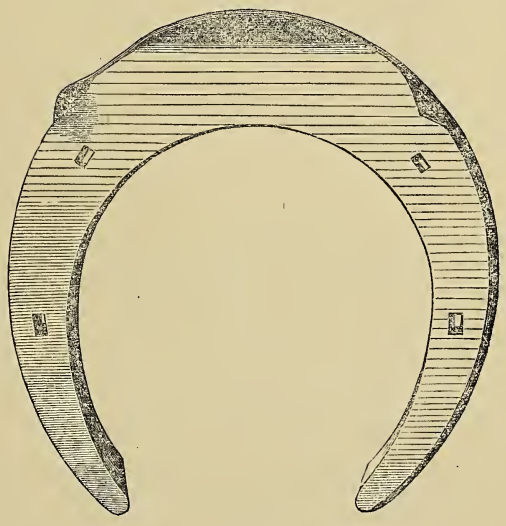
When the fitting of the shoe is completed, it may be made sufficiently warm to make for itself a seating or bed, so as to ensure the foot and the shoe having two planes as near as can be obtained; this can be done without destroying the texture of the adjacent horn. The crust which is thus removed, and by the previous operation of fitting the shoe, is generally found sufficient in working horses to reduce the foot to a healthy size.

The outer wall should under no pretence be rasped, the clinch should be simply knocked down, and not let into the crust by making a line with a rasp. Should any portion of horn project after the shoe is applied, it must on no account be rasped away but left; if this is strictly adhered to the hoof never becomes brittle or splits and a shoe rarely if ever lost.

The sole of the foot should not be pared in the least, nor the frog unless very ragged, and the ragged portions likely to collect and retain dirt and moisture, then the dead portions only should be cut off; but when a frog is not interfered with but allowed to receive a due amount of pressure, it will be found fully developed in a short space of time.

Now, as to the shape of shoe which best answers the purposes previously described, viz., lightness, durability, and requiring few nails.

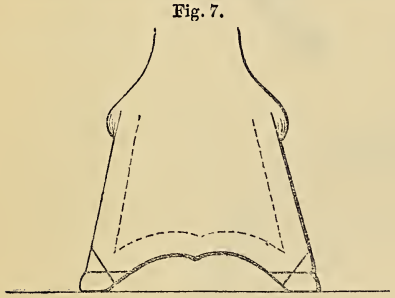




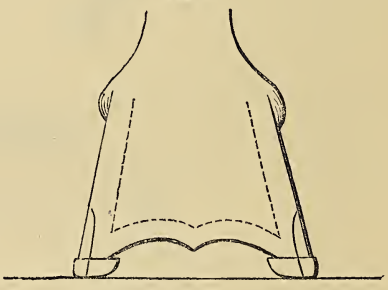
By referring to the plates, which represent the ground and foot surfaces of the shoe, you will observe that the shoe is much wider at the toe than elsewhere; this on the principle of an arch gives great strength, much greater than if the iron was thicker and the web narrower; so that the shoe can be made thinner and lighter without fear of breaking at the toe or spreading, one of which results not unfrequently occurs when it is light, and at the same time narrow at the toe.

The toe of the shoe is slightly turned up, thus removing it from the great amount of wear, which in nearly all cases it is subject to ; it also frequently prevents horses from stumbling when tired, as instead of an abrupt edge, a rounded surface strikes the irregularity in the act causing stumbling, so that the foot is not so completely checked in its advance, and the animal's equilibrium is not thereby so easily overcome. The portion turned up also acts as a clip, preventing the shoe moving backwards. The surface next to the foot is perfectly flat, and rests on the sole. The ground surface is bevelled, thus protecting the heads of the nails from too much wear, and offering no line or cavity whereby a stone can lodge or become wedged. The web of the shoe is gradually brought very narrow at the heels, its outer rim corresponding exactly with the crust, and the heel of the shoe terminating at the heel of the foot, thus offering protection to the crust only, and without presenting any surface to be trodden upon or allowing of the least suction in heavy ground. In short, the shoe should merely represent a continuation of the crust. The nail-holes are in the centre of the web, and directed outwards, the foot having been properly prepared as stated above, the nails pass directly through the horn, secure a good hold, without in any way approaching and interfering with the sensitive parts. The point of the nail thus driven need not be higher than three-quarters of an inch. The advantages of this system of nailing on the shoe are thus shown. Fig. 7 representing the system I advocate, and Fig. 8 the usual method.

Fig. 7.



Fig, 8.



It will thus be seen that the nail holds by a greater portion of horn, without interfering with the sensitive parts, and is less likely to cause the horn to split. The two small side clips give great support to the shoe, and their presence necessitates the smith fitting the shoe to the foot instead of the foot to the shoe. They in no way prevent expansion, as no such thing exists at that part of the foot. The smallest sized nails should invariably be used and fitted into each nail-hole before applying the shoe; the head of the nail should project so much only out of the nail-hole, as to insure that the "counter-sink" is quite filled.

To recapitulate ; allow of no paring or rasping, have plenty of horn left in which to drive the nails, use very small nails, do not allow them to be driven higher than three-quarters of an inch, and have a light shoe made of good material ; the pattern shoe is intended for near or off, hind or fore.

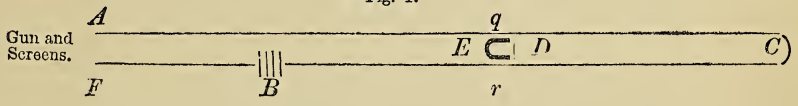
Prevent your horse always standing on an incline plane when in the stables, by insisting upon his being loose; do not have his feet stopped, but merely washed; there is no necessity for the sole being soft, as the horse stands upon an arch, and is supported by the crust or wall. See that these simple rules are strictly carried out, and your horse will carry you safely over the roughest of roads, and will not be continually in pain when in action.

67. The Chronograph described in the "Proceedings" of the R.A. Institution for 1866* has been successfully employed in determining the resistance of the air to the motion of spherical and elongated projectiles, varying from 3 to 9 inches in diameter. A simple instrument on the same principle has been constructed for use in those cases where the determination of the velocity of a shot at a given point is all that is required. Any one acquainted with the use of the ordinary drawing scale would be able to take the management of this instrument, because the necessary calculations are of the most elementary kind, and the arrangements are such that no very nice adjustment of the strength of the electro-magnets is required.

As in the original instrument a fly wheel is mounted upon a vertical axis, which carries a cylinder covered with paper. But in order to avoid the use of a clock, the time is given by a ball, which falls from rest through a known space. In the new instrument there is only one galvanic current, so that the time and screen records are made by the same marker, be it a mechanical dotter, or a spark from a Ruhmkorff's coil. As the whole time occupied by an experiment is less than the time of revolution of the fly wheel, the stage which carries the marker is clamped in one position during each experiment.

The principal difficulties which had to be overcome were:—(1) to avoid the disturbing influence of remaining magnetism in the recording electro-magnet; and (2) to provide an arrangement which would secure the breaking of the galvanic current with perfect certainty exactly at the instant when the ball was set free to fall. The manner in which the disturbing influence of remaining magnetism has been avoided may be thus explained without entering into details. The galvanic current is conducted to the gun, to the screens, to the chronograph *C*, to the apparatus

Fig. 1.



ED for dropping the ball at the proper time. When the keeper *D* is pressed by hand against the electro-magnet *E*, a kind of switch is moved which allows the galvanic current to pass through the coils of the electro-magnet *E*, and at the same time the chronograph *C* is excluded from the circuit. The circuit is then *A*, *q*, *r*, *B*, *F*. But if the current is interrupted for a moment the electro-magnet *E* becomes demagnetised, the keeper *D* is drawn back by a spring which moves the switch again so as to turn the current through *C* and exclude the electro-magnet *E*. The electro-magnet *E* can only recover its magnetism when the keeper *D* is again pressed up by hand.

* Vol. V. p. 161, &c.

The contrivance for dropping the ball W is represented in Fig. 2. The galvanic

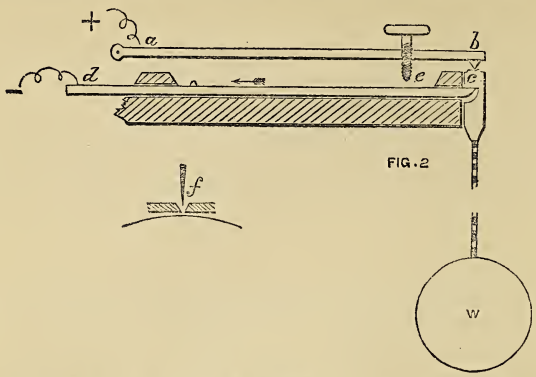


FIG. 2

current circulates through a, b, c, d, &c. When the bolt ed is suddenly drawn back in the direction of the arrow, the galvanic current is broken the instant contact ceases at c, and W begins to fall. The lever ab being unsupported, turns about its end a till the screw e comes in contact with the bolt dc. This restores the current ready for another record.

In order to measure a velocity, the fly-wheel is put in rapid rotation. The keeper D is pressed against the electro-magnet E, which shuts the chronograph C out of the circuit. When the lanyard is pulled it breaks momentarily the galvanic current. This allows the keeper D to be drawn back and so the galvanic current is turned through C. The marker is thus raised ready to record the exact time when the ball W is dropped. Arrangements are made so that after D has turned the galvanic current through C, it also draws back the bolt cd, Fig. 2, so as to release the ball W and break the current. Afterwards the shot passing through two or three screens breaks the current, and lastly, when the ball W has fallen through its appointed distance freely under the action of gravity, it strikes a small disc and permanently stops the current. It is obvious that arrangements will have to be made so that the extreme screen records may fall, as near as possible, equally distant from the records made by the falling weight W. When these arrangements have been made the result may be represented as follows :

$$\begin{array}{ccccccc} | & & & & & & | \\ & A' & & a' & & b' & & c' & & B' & \end{array}$$

Where A' represents the record corresponding to the instant when the ball W begins to fall, and B' that when W has fallen through its appointed space. a',b',c' are the records of the time of passing three equidistant screens, the use of the central one being to test the value of the records, because $b'c'$ ought to exceed $a'b'$ by a certain known quantity. But $a'c'$ would be used in calculating the velocity. Suppose the height of fall of W to be adjusted so as to occupy half a second, then $A'B'$ may be taken to represent half a second on the same scale as $a'c'$ represents the time occupied by the shot in passing from the first to the third screen, say 200 feet, for the angular velocity of the fly-wheel would not sensibly vary during the short time of half a second. But even if there was a slight sensible uniform loss of velocity in this short space of time, provided b' fell near the middle point between A' and B', no sensible effect would be produced in the resulting velocity. The time therefore occupied by the shot in passing over 200 feet would be equal to $\frac{a'c'}{A'B'} \times$ half a second; and the velocity of the shot would be equal $200 \times \frac{A'B'}{a'c'} \times 2 = 400 \times \frac{A'B'}{a'c'}$ feet per second. The resulting velocity might be read off at once without calculation on a good slide rule.

Originally it was proposed to use the spark as the recording agent in the first instrument constructed, but it was abandoned in that case because it was believed that there was a considerable amount of uncertainty in its action. Even at the present day it does not appear that any satisfactory experiments have been made by its aid, although it has so frequently been proposed to use it. The velocities obtained by the use of Schultz and Vignotti's instruments when they were placed in the *same* circuit differed remarkably, and in both instruments the records were made by a spark from a coil*. Still this would be a most useful recording agent if it could be relied upon. An attempt has therefore been made to retain it. Between the conducting point and the paper a piece of glass is placed in which there is a conical hole having a small opening, and the discharges are made from the point *f* Fig. 2 through this opening. If the spark be not satisfactory then mechanical means must be used.

The following is an arrangement of a much more simple nature, but it would require the exercise of care in adjusting the strength of the galvanic currents. Suppose that the first screen, an electro-magnet capable of supporting a ball, and an electro-magnet capable of working a relay, are all brought into one galvanic circuit. Suppose the same thing done for the second screen but quite independently of the first screen. When the first screen is broken the corresponding weight is dropped and the primary current of the Ruhmkorff's coil is broken so that a record a_1 is made on the revolving cylinder. When the shot breaks the second screen the second ball is dropped and a spark record b_1 is made on the cylinder. When the ball liberated by the shot at the first screen has fallen through a space corresponding to some known time, as half a second, it permanently stops the first current and gives a record a_2 on the cylinder. When the second ball has fallen through an equal space it gives a record b_2. The records will stand thus—

| . . . . |
a_1 b_1 a_2 b_2

where a_1a_2 represents the time occupied by the first ball in falling through its assigned space, and b_1b_2 the time occupied by the second ball in falling through an equal space. a_1a_2 ought therefore to be equal to b_1b_2 if the angular velocity of the cylinder has continued uniform, or a_1a_2 ought to be very slightly greater than b_1b_2 if there has been any slight loss in the angular velocity of the cylinder. a_1b_1, or a_2b_2 will represent the time occupied by the shot in passing between the two screens. This arrangement is open to the objection that the records may be affected by remaining magnetism, just as in the arrangements of Navez, Leurs, or Boulengé, but it possesses the recommendation of greater simplicity.

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* Benet's Electro Ballistic Machines. New York, 1866. p. 47.

68. Mitrailleur Christophe et Montigny*.—The Mitrailleur is a machine gun intended to throw "Mitraille" *i. e.* groups of small projectiles independently to distances of 1000 yards, to be used against troops under certain circumstances and to replace shrapnel.

There are several types of this machine. The Fafchamps, Agar, Gatling, the French service gun, the Montigny and others, Russian and American.

During the American war the Agar and Gatling guns were used with considerable effect.

The French have now formed batteries of these weapons constructed on a principle almost identical with the Montigny, and expect great things from their use.

The Montigny consists of thirty-seven rifled steel barrels hexagonally formed exteriorly, and fitted and soldered into a wrought-iron tube somewhat in the form of an ordinary piece of artillery, this has a moveable breech piece worked by means of a lever and containing a spring and striker corresponding with each barrel. The whole of the barrels can be charged simultaneously by the introduction of a steel plate containing the thirty-seven cartridges; they can be fired independently and at any intervals of time, or the whole may be fired in one second; reloading takes five seconds, and a continuous fire at the rate of ten discharges per minute can be maintained.

The gun is provided with both vertical and horizontal adjustments, and may be made to sweep horizontally along a line by adjustment between each discharge, or during the discharge itself.

As there is no recoil, the gun once laid, will continue to throw 28lbs. weight of projectiles per minute on the same spot, or on various points of any line requiring the same elevation, without any further labour than that involved in the working of the lateral adjustment.

The following particulars may possess interest:—

Mitrailleur Christophe et Montigny.

Weight, 400lbs., No. of barrels 37.
Calibre, ·534 inches.
Rifling, Metford.
Hardened bullet, weight 600 grains.
Charge of powder, 115 grains.
Rapidity of fire, ten rounds = 370 shots per minute.
Mean absolute deviation at 500 yards, 31 inches.
Mean of elevation at 500 yards, 1° 24′.
Mean absolute deviation, 800 yards, 51 inches.
Angle of elevation 800 yards, 2° 5′.
Angle of elevation 1000 yards, 2° 35′.

69. Dogwood Charcoal.—The wood known as black dogwood, and used for gunpowder in this and other countries, is not dogwood (*Cornus*), but is properly the Alder Buckthorn (*Rhamnus frangula*). Black dogwood is the popular name that has always been given to this wood in England.

Chemists that have made experiments with charcoal from a great variety of woods by mixing 12 parts by weight of charcoal with 60 of saltpetre assert that this wood yields the greatest volume of gas in decomposition, next the willow, and then the alder.

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* By Major G. F. Fosberry, V.C., Bengal Staff Corps.

Small Arm Ammunition in the British Service. 1869.

Description	Charge. Drams of 27·34 grains.	Bore.	Bullet. Diameter.	Bullet. Length	Bullet. Weight without plug.	Bullet. Weight with plug.
		inches.	inches.	inches.	grs.	grs.
Cartridges, small arm, percussion — ball — breech-loading, Boxer's — buck shot	2¼	0·577	16 Buck shot.		520	
breech-loading, Boxer's — service†	2½	0·577	0·573 (over lubrication 0·575)	1.04	468½	480
carbine — rifled — breech-loading — Sharps'*	2¼	0·551	0·568	1·107	560	—
carbine — rifled — breech-loading — Terry's*	2	0·539	0·568	0·983	530	—
carbine — rifled — breech-loading — W. Richards'*	2	0·449 / 0·451	0·468 / 9·448	1·015	400	—
carbine — rifled — muzzle loading — Arty. and Cavly.	2	0·577	0·55	1·095	524	536
carbine — rifled — muzzle loading — Paget's	1¾	0·685	0·675	1·003	700	—
carbine — smooth bore — carbine bore — buck shot	2½		7 Buck shot.		378	—
carbine — smooth bore — carbine bore — service	2½	0·656	0·60	—	350	—
carbine — smooth bore — Victoria*	2½	0·753	0·68	—	483	—
musket smooth bore — buck shot	3½	0·753	12 Buck shot.		648	—
musket smooth bore — service*	4½	0·753	0·68	—	483	—
rifle muzzle-loading — 1842*	2¾	0·758	0·731	1·073	813	825
rifle muzzle-loading — 1851*	2½	0·702	0·675	1·025	662	670
rifle muzzle-loading — 1853 and Lancaster carbine	2½	0·577	0·55	1·095	524	536
rifle muzzle-loading — Brunswick belted*	2½	0·577 / 0·593	71 / 77	—	555	—
pistol — rifle — revolver — muzzle-loading	1	0·577	0·568	0·863	390	—
pistol — rifle — revolver — Adams' (B.L.)	13 grs.	0·434	0.455	0·765	225	—
pistol — rifle — revolver — Colts'	13 ,,	0·358	0·38	0·612	135	—
pistol — rifle — revolver — Deane and Adams'	15 ,,	0·434	0·457	8·63	214	—
pistol — smooth bore — carbine bore*	2	0·656	0·60	—	350	—
pistol — smooth bore — pistol bore	2	0·570	0·51	—	205	—
Cartridges, small arm, percussion — blank — All arms (except those named below) — breech-loading, Boxer's†	2½	0·577	—	—	—	—
blank — All arms (except those named below) — muzzle-loading	3½	0·753	—	—	—	—
blank — carbine breech-loading — Sharps'*	3	0·551	—	—	—	—
blank — carbine breech-loading — Terry's*	3	0·539	—	—	—	—
blank — carbine breech-loading — Westley Richards'*	75 grs.	0·449 / 0·451	—	—	—	—
blank — pistol, sea service	2	0·570	—	—	—	—

* These descriptions of ammunition are gradually being withdrawn.

† For all Snider arms 0.577 inch bore.

E. M. BOXER, Colonel, R.A.,
Superintendent Royal Laboratories.

Approved by Secretary of State for War.
J. H. LEFROY, Major General, R.A.,
Director General of Ordnance.

Arms in use in the British Service, 1869.—*Smooth-Bored Muzzle-Loading.*

Arm.	Musket. Weight With Bayonet or sword.	Musket. Weight Without Bayonet or sword.	Musket. Length With Bayonet or sword.	Musket. Length Without Bayonet or sword.	Boyonet or sword. Weight.	Boyonet or sword. Length beyond muzzle.	Boyonet or sword. Weight of scabbard.	Barrel, dimensions. Weight.	Barrel, dimensions. Length.	Barrel, dimensions. Diameter of bore.	Charge.	Service.	Date of approval of pattern.
	lbs ozs	lbs ozs	ft. ins.	ft. ins.	lbs ozs	ft. ins.	ozs.	lbs ozs	ft. ins.	inches	drms.		
Carbines — interchangeable, Cavalry, ·656 ...	—	5 6	—	3 0¾	—	— —	—	2 3	1 9	·656	3	Indian. Native Cavalry.	21. 3. 67.
Carbines — non-interchangeable — Constabulary, ·656	8 6½	7 10	4 10⅝	3 9¼	— 12½	1 1⅝	—	3 4½	2 5	,,	,,	,, ,, Police.	14. 10. 58.
Carbines — non-interchangeable — Police — Foot	8 5½	7 8	5 4¾	3 11¼	— 12½	1 5½	4½	2 15	2 7½	,,	,,	,, ,, ,,	14. 10. 58. / 17. 12. 58.
Carbines — non-interchangeable — Police — Mounted	—	6 9	—	3 0¾	—	—	—	2 4½	1 9	,,	,,	,, ,, ,,	14. 10. 58. / 17. 12. 58.
Carbines — non-interchangeable — Sappers, pattern '58	9 7	7 10¼	5 11⅛	3 11⅛	1 8¾	2 0	9¾	3 5½	2 7½	,,	,,	,, ,, Sappers.	14. 10. 58. / 17. 12. 58.
Muskets, ·656, interchangeable — Long, pattern '59	9 6	8 10¼	6 0	4 6½	— 11¾	1 5½	4½	4 0½	3 3	,,	,,	,, ,, Infantry.	7. 5. 59.
Muskets, ·656, interchangeable — ,, '58	9 6	8 8¾	6 0	4 6½	— 13½	1 5½	4½	3 6½	3 3	,,	,,	,, ,, ,,	19. 5. 58.
Muskets, ·656, interchangeable — Serjeants' fusil.....	8 8½	7 12¾	5 6½	4 0¾	— 12	1 5¾	4½	3 5	2 0	,,	,,	,, Serjeants Native Infantry.	14. 10. 58. / 17. 12. 58.
Pistols ..... — East India, 8 inch	—	2 8½	—	0 13½	—	—	—	0 15	0 8	,,	2	,, ,, Cavalry.	
Pistols ..... — Naval, 6 inch	—	2 3½	—	0 11⅝	—	—	—	0 12¼	0 6	·570	2	Coast Guard.	7. 5. 59.

W. DIXON, Colonel, R.A.,
Superintendent, R.S.A.F.

Approved by the Secretary of State for War,

J. H. LEFROY, Major-General, R.A.,
Director General of Ordnance.

	Rifles.		Arm sighted to.	Charge of powder.	Service.	Date of approval of pattern.
	Description.	Twist of rifling.				
			yds.	drs.		
RIF						
inter	Pro-gressive.	1 in 48	600	2½	Royal Artillery, Military Store Staff Corps, Commissariat Staff Corps, & Military Train.	2. 5. 67. 7669/1009
§	,,	1 in 48	600	2½	Regiments of Cavalry, except Lancers.	1. 5. 67. 7669/999
	,,	1 in 78	—	2½	Convict and Prison Guards.	
Carbines	Uniform	1 in 48	600	2¼	Cavalry Regiments serving in India.	
	Pro-gressive.	1 in 78	900	2½	Irish Constabulary and Singapore Volunteers.	16. 7. 67.
	,,	Vari-able.	1150	2½	Royal Engineers.	31. 10. 66. 7669/557
inter	Uniform	1 in 36	500	2	Cape Mounted Rifles, but it is expected will soon be withdrawn.	
	,,	1 in 20	800	2	These arms are at present in store.	7. 3. 66. 81 R / 676
	,,	1 in 24	—	13	Metropolitan Police.	2. 12. 67. 203/502
Pistols, revolve	,,	1 in 36	—	13 grs.	Royal Navy, Police, and Constabulary.	—
	Uniform	1 in 20	—	15		
	Pro-gressive.	1 in 78	950	2½	Line, permanent Staff of Militia, Royal Marines, 7 Militia Regiments, and Enrolled Pensioners.	18. 9. 66. 7669/463
	Pro-gressive.	1 in 78	950	2½	,, ,,	
Rifles, Snider's — interchange	,,	1 in 48	1000	2½	Royal Navy and Coast Guard.	21. 8. 67. 7669/1232
	,,	1 in 48	1000	2½	Serjeants of Line, permanent Staff of Militia, Royal Marines, 7 Militia Regiments, Enrolled Pensioners, Rifle Regiments, and Royal Marine Artillery.	—
non-interch	,,	1 in 48	1000	2½	Royal Navy and Coast Guard.	21. 8. 67. 7699/1232
RIFI						
inter pat	Pro-gressive.	1 in 43	600	2	Militia and Artillery Volunteers.	
3	,,	1 in 78	300	2	Militia and Artillery Volunteers.	
Carbines 3	,,	1 in 78	300	2	Indian. European Cavalry.	7. 8. 56. x/18,455
	,,	Vari-able.	1000	2½	Engineer Volunteers.	
inter 8	,,	1 in 78	300	—	Yeomanry.	
3	,,	1 in 78	1000	2½	Indian. European Sappers.	11. 8. 56. x/13,484
3	,,	1 in 48	300	2	Yeomanry Cavalry.	
Pistols 3	,,	1 in 48	300	1	Lancer Regiments, and Troop Serjeant-Majors of Cavalry.	8. 11. 60. 77 / 19 / 167
3	,,	1 in 48	100	1	Indian. European Cavalry.	17. 12. 58. 77 / 22 / 74
3	,,	1 in 78	1000	2½	Militia and Volunteers.	2. 4. 60. 77 / 15 P. / 660
3	,,	1 in 78	1000	2½	Serjeants of Militia & Volunteers.	
Rifles — interchange 3	,,	1 in 48	1250	2½	Serjeants of Militia & Volunteers.	
1	Uniform	1 in 30	300	2½	Indian. Sikhs.	18. 1. 37. C/14
non-interchange 3	,,	1 in 78	1100	2½	Serjeants of Militia & Volunteers.	
3	Pro-gressive.	1 in 78	1100	2½	Indian. Serjeants of European Infantry.	11. 8. 56. x/18,484

* The
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§ The
‖ Will
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the cavalry 8 inch have no back sights.

converting them into "pistol carbines" for special service.

lonel, R.A., Superintendent, R.S.A.F.

Arm.	Musket. Weight. with Bayonet or sword.	Musket. Weight. without Bayonet or sword.	Musket. Length. with Bayonet or sword.	Musket. Length. without Bayonet or sword.	Bayonet or sword. Weight.	Bayonet or sword. Length beyond muzzle.	Bayonet or sword. Weight of scabbard.	Barrel. Dimensions, &c. Weight.	Length.	Diameter of bore.	Diameter of at muzzle. Major axis.	Diameter of at muzzle. Minor axis.	Diameter of at breech. Major axis.	Diameter of at breech. Minor axis.	Grooves. Number.	Width.	Depth. Muzzle.	Depth. Breech.	Description.	Twist of rifling.	Arm sighted to.	Charge of powder.	Service.	Date of approval of pattern.
RIFLE BREECH-LOADING.	lbs ozs	lbs ozs	ft. ins.	ft. ins.	lbs ozs	ft. ins.	ozs.	lbs ozs	ft. ins.	ius.	inch.	inch.	inch. Cham ber.	inch. ber.		ins.					yds.	drs.		
Carbines — interchangeable, Snider's — Pattern '61 — Artillery	9 3	7 7	5 3	3 4½	1 12	1 10¾	12	3 6½	2 0	0·577	—	—	0·673	0·630	5	0·235	0·005	0·011	Progressive.	1 in 48	600	2½	Royal Artillery, Military Store Staff Corps, Commissariat Staff Corps, & Military Train.	2. 5. 67. 7669/1009
Carbines — interchangeable, Snider's — Pattern '61 — Cavalry	—	6 10½	—	3 0⅞	—	—	—	3 2¾	1 9⅝	,,	—	—	,,	,,	5	0·235	0·005	0·011	,,	1 in 48	600	2½	Regiments of Cavalry, except Lancers.	
Carbines — interchangeable, Snider's — *Convict Guard	7 12½	7 1	4 6¾	3 4¼	0 11½	1 2½	4	3 8	2 0	,,	—	—	,,	,,	3	0·235	0·008	0·013	,,	1 in 78	—	2½	Convict and Prison Guards.	1. 5. 67. 7669/999
Carbines — non-interchangeable — Sharps'	—	7 7	—	2 11½	—	—	—	2 8½	1 6	0·551	—	—	0·577	—	3	0·214	0·013	0·013	Uniform	1 in 48	600	2¼	Cavalry Regiments serving in India.	
Carbines — non-interchangeable — Snider's — Constabulary	8 14	7 8	4 11	3 5	1 6	1 6	7½	3 8¼	2 1	,,	—	—	,,	,,	3	0·235	0·008	0·011	Progressive.	1 in 78	900	2½	Irish Constabulary and Singapore Volunteers.	16. 7. 67.
Carbines — non-interchangeable — Snider's — Lancaster	9 12½	8 1¾	5 11½	3 11½	1 10½	2 0	9¾	4 2¼	2 7½	0·557	0·593	0·577	0·598	0·580	Oval bore.				,,	Variable.	1150	2½	Royal Engineers.	31. 10. 66. 7669/557
Carbines — non-interchangeable — Terry's	—	6 3½	—	3 1⅝	—	—	—	3 0	1 9	0·539	—	—	0·577	—	5	0·175	0·013	0·013	Uniform	1 in 36	500	2	Cape Mounted Rifles, but it is expected will soon be withdrawn.	
Carbines — non-interchangeable — Westley Richards'	—	6 8	—	2 11⅞	—	—	—	2 5	1 8	0·449	—	—	0·485	—	8	—	0·008	0·008	,,	1 in 20	800	2	These arms are at present in store.	7. 3. 66. 81/R/676
Pistols, revolver — Adams'	—	2 7	—	1 0⅝	—	—	—	—	0 6	0·443	—	—	0·480	0·451	5	0·215	0·005	0·005	,,	1 in 24	—	13	Metropolitan Police.	2. 12. 67. 203/502
Pistols, revolver† — Colt's, 84 guage	—	2 9½	—	1 1¾	—	—	—	0 11	0 7½	0·358	—	—	0·374	—	7	0·08	0·010	0·012	,,	1 in 36	—	13 grs.	Royal Navy, Police, and Constabulary.	—
Pistols, revolver† — Deane's, 54 guage‡	—	2 6½	—	1 8	—	—	—	—	0 5¾	0·434	—	—	0·451	—	3	0·305	0·009	0·009	Uniform	1 in 20	—	15		
Rifles, Snider's — interchangeable — Long, pattern '53 — long butts	9 14¼	9 0¾	6 0½	4 7	0 13½	1 5½	4½	4 10½	3 3	0·577	—	—	0·670	0·630	3	0·235	0·005	0·012	Progressive.	1 in 78	950	2½	Line, permanent Staff of Militia, Royal Marines, 7 Militia Regiments, and Enrolled Pensioners.	18. 9. 66. 7669/463
Rifles, Snider's — interchangeable — Long, pattern '53 — short ,,	9 12½	8 14¾	5 11½	4 6	0 13½	1 5½	4½	4 10½	3 3	,,	—	—	,,	,,	3	0·235	0·005	0·012	Progressive.	1 in 78	950	2½	,, ,,	
Rifles, Snider's — interchangeable — Naval, pattern '58§	11 0¼	8 10¼	6 3⅝	4 0½	2 6	2 2⅞	10¼	4 8¼	2 9	,,	—	—	,,	,,	5	0·235	0·005	0·011	,,	1 in 48	1000	2½	Royal Navy and Coast Guard.	21. 8. 67. 7669/1232
Rifles, Snider's — interchangeable — Short, pattern '60	10 7½	8 12	5 11¼	4 0½	1 12	1 10¾	7½	4 8¼	2 9	,,	—	—	,,	,,	5	0·235	0·005	0·011	,,	1 in 48	1000	2½	Serjeants of Line, permanent Staff of Militia, Royal Marines, 7 Militia Regiments, Enrolled Pensioners, Rifle Regiments, and Royal Marine Artillery.	—
Rifles, Snider's — non-interchangeable, Naval, pattern '58	11 0¼	8 10¼	6 3⅝	4 0½	2 6	2 2⅞	10¼	4 8¼	2 9	,,	—	—	,,	,	5	0·235	0·005	0·011	,,	1 in 48	1000	2½	Royal Navy and Coast Guard.	21. 8. 67. 7699/1232
RIFLED MUZZLE-LOADING.																								
Carbines — interchangeable, pattern, '61 — Artillery	9 12	7 4¼	5 3	3 4¼	1 12	1 10¾	14	3 0	2 0	,,	—	—	—	—	5	0·235	0·005	0·013	Progressive.	1 in 43	600	2	Militia and Artillery Volunteers.	
Carbines — non-interchangeable — Artillery, pattern '53	9 12	7 4¼	5 3	3 4¼	1 12	1 10¾	14	3 0	2 0	,,	—	—	—	—	3	0·235	0·005	0·013	,,	1 in 78	300	2	Militia and Artillery Volunteers.	
Carbines — non-interchangeable — Cavalry, pattern '56	—	6 9½	—	3 0⅜	—	—	—	2 9¾	1 9	,,	—	—	—	—	3	0·235	0·005	0·013	,,	1 in 78	300	2	Indian. European Cavalry.	7. 8. 56. x/18,455
Carbines — non-interchangeable — Lancaster	9 9⅜	7 6½	5 11½	3 11½	1 10½	2 0	9¾	3 9	2 7½	,,	0.593	0·577	0·598	0·580	Oval bore.				,,	Variable.	1000	2½	Engineer Volunteers.	
Carbines — non-interchangeable — Paget's‖	—	5 6½	—	2 7¾	—	—	—	1 14½	1 4	0·686	—	—	—	—	3	—	0·008	0·008	,,	1 in 78	300	—	Yeomanry.	
Carbines — non-interchangeable — Sappers' pattern '56	9 11¾	8 3	5 11¾	3 11¾	1 8¾	2 0	9½	3 10½	2 7½	0·577	—	—	—	—	3	0·235	0·005	0·013	,,	1 in 78	1000	2½	Indian. European Sappers.	11. 8. 56. x/13,484
Carbines — non-interchangeable — Carbine, with movable handle	—	4 11	—	2 2⅛	—	—	—	1 4½	0 10	,,	—	—	—	—	5	0·235	0·005	0·013	,,	1 in 48	300	2	Yeomanry Cavalry.	
Pistols — Cavalry, 10 inch¶	—	3 2	—	1 3¾	—	—	—	1 4½	0 10	,,	—	—	—	—	5	0·235	0·005	0·013	,,	1 in 48	300	1	Laneer Regiments, and Troop Serjeant-Majors of Cavalry.	8. 11. 60. 77/19/167
Pistols — East India 8 inch	—	2 10¼	—	1 2	—	—	—	0 15¼	0 8	,,	—	—	—	—	5	0·235	0·005	0·013	,,	1 in 48	100	1	Indian. Enropean Cavalry.	17. 12. 58. 77/22/74
Rifles — interchangeable — Long, pattern '53 — long butts	9 12	8 14½	6 0½	4 7	0 13½	1 5½	4½	4 4	3 3	,,	—	—	—	—	3	0·235	0·005	0·013	,,	1 in 78	1000	2½	Militia and Volunteers.	2. 4. 60. 77/15 P./660
Rifles — interchangeable — Long, pattern '53 — short ,,	9 6	8 9	5 11½	4 6	0 13½	1 5½	4½	4 4	3 3	,,	—	—	—	—	3	0·235	0·005	0·013	,,	1 in 78	1000	2½	Serjeants of Militia & Volunteers.	
Rifles — interchangeable — Short, '60	10 4	8 8½	5 11¼	4 0½	1 11½	1 10¾	7½	4 1½	2 9	,,	—	—	—	—	5	0·235	0·005	0·013	,,	1 in 48	1250	2½	Serjeants of Militia & Volunteers.	
Rifles — non-interchangeable — Brunswick, pattern '37	11 3	9 2	5 6⅜	3 9½	2 1	1 9½	—	3 14½	2 6	0·704	—	—	—	—	2	0·278	0·031	0·031	Uniform	1 in 30	300	2½	Indian. Sikhs.	18. 1. 87. C/14
Rifles — non-interchangeable — Short, pattern '56	9 14½	8 2½	5 11¼	4 0½	1 12	1 10⅜	7½	3 10½	2 9	,,	—	—	—	—	3	0·235	0·005	0·013	,,	1 in 78	1100	2½	Serjeants of Militia & Volunteers.	
Rifles — non-interchangeable — Serjeants' fusil	9 3	8 6½	5 6½	4 0⅜	0 12½	1 5½	4½	3 14	2 9	,,	—	—	—	—	3	0·235	0·005	0·013	Progressive.	1 in 78	1100	2½	Indian. Serjeants of European Infantry.	11. 8. 56. x/18,484

* The Convict Guard arm has no back sight or nosecap; it has no rammer or rammer groove; and the stock is rounded at the nose.
† In Deane and Adams' pistols, the barrel and stock being in one, the weight of the barrel alone cannot be given. These pistols, as well as Colt's, Adams', and the cavalry 8 inch have no back sights.
In the revolvers the guage is measured by the number of spherical bullets to the pound.
‡ Will probably be converted on Adams' B.L. system.
§ The Naval rifle has a "*Cutlass Sword Bayonet.*"
‖ Will be withdrawn shortly.
¶ A movable butt has been made for some of the 10 inch pistols, weight 1 lb. 8¼ ozs., and for a few of Deane and Adams' 38 guage pistols, Weight 1 lb. 11 ozs., converting them into "pistol carbines" for special service.

W. M. DIXON, Colonel, R.A., Superintendent R.S.A.F.

70. Experiments with an $8\frac{3}{4}$-inch Krupp's steel gun at the Polygon of Brasschaet.*—The following experiments are of the greatest interest with regard to the defence of the Scheldt. Security of defence can only be effectually obtained by means of heavy ordnance sufficiently powerful to pierce the armour of the strongest vessels.

With a view to constructing new forts to complete the defences of the Scheldt at the angle of Saint Marie, it was of great use to determine the effect of solid shot and explosive projectiles from guns of the largest calibre, against parapets of sandy earth.

Consequently the government, after having collected all the information it could procure concerning experiments carried on abroad, ordered the hooped steel gun to be tried against earth parapets and against armour-plated targets, representing the sides of iron-clad ships, of the Warrior and Bellerophon types.

The following is the programme of the experiments:—

First Part.—To measure the tensions (with the Rodman apparatus) and the initial velocities; to compare the prismatic powder and the large grained Belgian powder, and to determine which to choose for firing against the armour-plates, for which purpose it was arranged to fire fifteen rounds with charges of twenty-one kilogrammes (46·30 lbs.) of prismatic powder from Prussia; fifteen rounds with Belgian large grained powder of 13 to 16 millimetres in (0·52 to 0·63 inches) diameter; and fifteen rounds with Belgian powder of 16 to 19 mill. (0·63 to 0·75 inches).

The cartridges to be of $0^m{\cdot}180$ to $0^m{\cdot}185$ in diam.

The charges to be regulated after obtaining the tensions and initial velocities.

The tensions not to exceed 3,100 atmospheres, and the initial velocities to be not less than 400 metres (1312·4 ft.) per second.

Cast iron projectiles to be used, of not more than 122 kilog. (269·45 lbs.) in weight, unless the tensions should fall short of the limit of 3,100 atmospheres, when they might be raised to 128 kilog. (282·19 lbs.)

These trials would serve besides to determine the depth of penetration of the projectiles.

(1) In a parapet of earth.

(2) In a similar parapet with two 1-inch iron plates inside.

Second Part.—To fire with the most effective kind of powder.

A. Against the plates.

Cast iron projectiles to determine the elevation for steel shell and cast projectiles.

B. Against armour-plated targets.

(1) Krupp's steel shell beginning with those manufactured in 1868.

(2) Palliser's shell of the English pattern.

(3) Palliser's solid shot (English and Belgian). The influence of the thickness of the lead-coating on the penetration into the armour-plates to be at the same time determined.

(4) The cast steel projectiles of the latest pattern, from the royal foundry at Liége, max. weight 128 kilog. (282·19 lbs.)

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* Extract from the Report to the Minister of War, in Belgium, 1868.

Only a sufficient number of rounds to be fired in each series to enable the results obtained and the effect of a salvo to be accurately determined.

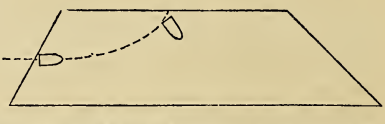
The initial velocities to be measured.

As there were a Norwegian steel shell and two steel shells from Seraing, at the Polygon, the committee was to decide, considering the state of the target, if it was convenient to fire them as well.

Conclusions on the subject of firing solid shot against a parapet.
A. Right half, without plates.

the parapet. The lower they hit, the higher they rise and the nearer to the exterior crest do they emerge.

Experience proves that elongated solid shot fired at a distance of 200 metres, (656·18 ft.) against a parapet of sandy earth, with an exterior slope of 45°, have a maximum penetration of $4^{m}{\cdot}30$. (13·12 ft.)



The projectiles rise within the parapet. Those which hit at $1^{m}{\cdot}50$ (3·28 ft.), and even at two metres below the crest, come out towards the exterior slope, and usually fall at only a short distance from the parapet. The lower they hit, the higher they rise and the nearer to the exterior crest do they emerge.

The projectiles which remain imbedded in the parapet, often have their heads downwards, and to the right.

The projectiles having all struck the parapet in a space of two square metres at most, sand may be concluded to be an extremely favorable material for the construction of epaulments.

B. Left side, with two plates inside fastened together, each $0^{m}{\cdot}025$, *or* 1 *inch thick.*

The plates placed at $4^{m}{\cdot}50$ (13·12 ft.) from the exterior crest of the parapet are too far off to be touched. They retard, however, the formation of the crater.

It would be interesting to fire against a parapet four metres thick, half of which was strengthened by two 1-inch plates, placed in the middle of the epaulment.

These conclusions relate to the results obtained, when after each round the earth has been thrown back into the crater.

The dimensions of the crater produced by the firing of twenty-six rounds, prove that it is quite impossible to cut away an 8-feet parapet of sandy earth so far as a metre below the line of fire.

It follows that a parapet of this kind can resist a prolonged firing of pieces of the heavest calibre throwing solid shot.

This experiment shews also that scarps will be completely protected from direct fire of heavy ordnance by counterguards with an excess of one metre in height.

Conclusions on the subject of firing shell against parapets.
Right side without plates.

The possibility of shells of the largest calibre, filled, but without fuzes, being made to burst in the earth, is a fact of the greatest importance, with a view to constructing coast defences.

The results obtained with Palliser shells containing a charge of $1^{k}.200$ (2·3 lbs.), and above all, the result of the bursting of Krupp's shell, containing a bursting charge of $2^{k}.545$ (4·42 lbs.), prove that if such projectiles were thrown into a merlon, the two embrasures would be filled up, and that if they burst in the embrasure itself, it would be destroyed, and the gun rendered unserviceable.

The committee conclude from this, that uncasemated batteries to be constructed on the Lower Scheldt, ought to be built en barbette with parapets of sandy earth, eight metres (26·25 ft.) thick.

Powder.—The large grained Belgian powder was not completely consumed in the gun.

Unconsumed remnants of grains were projected into the wood of the first and second framework.

At nightfall, ignited grains could be plainly seen as far as the second framework, fifty-five metres from the piece (180·45 ft.), and sometimes even about 30 metres (95·43 ft.) beyond that.

The Belgian powder left more residue in the gun than the prismatic powder.

71. Experiments with a Krupp's steel gun, at the Polygon of Brasschaet against iron-plated targets of the Warrior and Bellerophon types.*

Conclusions.

The results obtained in the experiments carried on against armoured targets of the Bellerophon and Warrior types, are of the highest importance.

(1) The $8\frac{3}{4}$-inch gun with a charge of 22 kilogrammes (48·49 lbs.) of prismatic powder, firing projectiles of 114 to 130 kilogrammes (251·32 lbs. to 286·6 lbs.), is *more than powerful enough* to penetrate iron-clad vessels, whether they are amoured with 8-*inch* plates backed with ten inches of oak and 1-inch plates within; or else with 7-*inch* plates backed with *eighteen inches* of wood and 1-inch plates.

(2) Krupp's steel shell (with thin lead-coating and large interior capacity) are most effective. They will be much more destructive if it should be found practicable to retard the bursting of the shell until they shall have pierced the plates and penetrated into the wood backing. This was nearly effected at the third round fired against the Warrior target. The projectile pierced it and loosened all the bolts.

Good results were obtained from the experiment of the committee in placing hemp wads above and below the bursting charge, which was of large grained powder *i. e.* 13 to 19 millimetres (0·52 ins. to 0·75 ins.) in diameter.

This experiment should be continued further, so as to retard the bursting of the shell still more.

The Krupp shell, filled with sand, pierced the Bellerophon target, whilst retaining a considerable portion of its lead coating, thus pronouncing in favour of the zinc attachment.

(3) The solid shot of Palliser's casting (with English lead coating) were *of an excellent quality.*

(4) Palliser's shell fired against the Bellerophon target gave good results, but not so good as those obtained with Krupp's shell.

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* Extract from the Report to the Minister of War, in Belgium, 1868.

The *interior capacity of the English projectile is too small.* As there are no means of enlarging it sufficiently without weakening the sides of the shell, the committee consider that the Palliser mode of casting should be restricted to the manufacture of *solid shot.*

(5) The solid steel shot of Belgian casting were effective ; but if it is considered that two of them, fired against the Bellerophon target already weakened and partly disjointed by former rounds, were broken to pieces, although they struck close to the holes made by two former rounds, one must see that, for the present, at least, and without regard to future improvements in their manufacture, they cannot be placed in comparison with the Palliser projectiles.

(6) To ascertain the influence which the thickness of the lead-coating has on the penetration, the committee fired a projectile of the Belgian casting against the Bellerophon target, with a charge of 21 kilogs. (46·3 lbs.) of large grained powder 13 to 16 millimetres (0·52 ins. to 0·63.) By thus reducing the initial velocity, they hoped to be able to judge better of the influence of a thick lead-coating; but they were disappointed in this by the demolition of the target.

(7) On examination, the results obtained in the practice against these two targets, prove that the holes made in the plates by the Krupp projectiles with thin lead-coating are relatively greater than those produced by the English Palliser and the Belgian steel projectiles.

We say "relatively" because the difference between the diameter of the hole made in the target by a Krupp's shell and that of the shell itself is greater than the corresponding difference for an English or Belgian projectile.*

This result was foreseen. When a thickly coated projectile strikes a plate with a sufficient velocity, the lead is torn off and the body alone of the projectile passes through the target. Part of the power is lost in the smashing of the projectile and in the stripping of the lead. The effective force on the plate depends then, in reality, on the weight, form, resistance and velocity at impact, of the body only of the projectile.

The projections (for holding the lead-coating) on the projectile of the Belgian form diminish the penetration, since they strike against the edges of the hole made in the target.

Besides, the diameter of the projectile is smaller at the head 211 millimetres (8·32 ins.) than at the base 218 millimetres (8·56 ins.), and this difference must be torn away to enable the projectile to pierce through the plate ; from this source also power is lost.

It is advantageous, then, to adopt the system of lead-coating with zinc attachment, and the exterior form of Krupp's shell, the body of which has no projections.

Krupp's shell, not filled, weighing on the average 111 kilogs. (244·8 lbs.), is coated with only 7 kilogs. (15·43 lbs.) of lead, or about $\frac{1}{16}$th of the weight of the projectile ; while for the Belgian and Palliser projectiles weighing amean of 128 kilogs., (282·19 lbs.), the weight of the lead-coating is 17 kilogs. (37·48 lbs.), or $\frac{1}{7}$th the weight of the projectile.

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* The diameter of the body of a Krupp's shell is 217 millimetres (8·55 ins.) ; of the English projectile, 211 millimetres (8.32 ins.) ; of the Belgian, 210 millimetres (8·28 ins.)

(8) It has not been possible to determine if, with regard to the penetration into the plates, the English coating of the Palliser projectiles is better than the Belgian coating of projectiles of the same kind.

(9) The construction of the target of the Bellerophon type, left nothing to be desired.

The iron plates were very good.

The 7-in. plate of the Warrior target appeared inferior to the 8-in. plate of the Bellerophon target. It was, however, of a good quality.

General Conclusions.

The committee think it may be well to recapitulate the different conclusions which they have drawn in their report, as follows:—

(1) The question of guns of heavy calibre destined for the defence of the Scheldt is solved.

The $8\frac{3}{4}$-inch Krupp's steel gun is sufficiently powerful to pierce the strongest armour-plated vessels actually afloat, which can enter the river. The gun is easily managed. The closing of the breech is perfect.

(2) The casting in chill (Palliser) satisfies the conditions requisite for the manufacture of solid shot; and Krupp's steel is suitable for shell.

Both kinds of projectiles should be lead-coated with the zinc attachment.

(3) The Belgian solid shot of cast steel, though less penetrating than the English solid shot, might be used on an emergency, but the form of their lead-coating and the mode of attachment should be modified.

(4) The ignition of the bursting charge of the shells should be retarded, and consequently the powder should not be put in loose.

(5) Prismatic powder is suitable for heavy steel guns, but it will be interesting to try if powder in large round grains cannot be used with advantage, in its stead.

(6) The charges of heavy guns should be prepared beforehand, and be carefully protected from damp.

(7) The guns should be fired by electric tubes in preference.

(8) Iron carriages are the most suitable for the armament of the banks of the Scheldt.

For the cupolas the muzzle pivotting system is best; and for un-casemated batteries it is desirable that carriages should be used which sink the gun below the parapet, out of reach of the fire of the enemy.

(9) The parapet of the batteries to be constructed on the Lower Scheldt, should be of sandy earth and eight metres thick.

(10) Heavy guns in uncasemated batteries should be mounted en barbette.

72*

Minute 27,552. $\frac{1314.}{2}$ Boxer Shrapnel Shells for rifled Guns.

1671 g. Segment Shells.

Dartmoor experiments.

D. G. O., 22. 11. 69., forwards for record, with reference to *Minute* 26,974, a copy of the report of the Special Committee on shrapnel *v.* segment shell, dated 18. 9. 69., which has been printed at the War Office.

The following are the abstracts of the results of the various experiments :—

1. *Deliberate Practice.*

Abstract showing the average number of hits per effective round, allowing throughs, lodges, and two-thirds of the strikes to count.

9-POUNDER B.L. GUN.

Shrapnel.			Segment.						Targets.	Hits per round.		
			Time & percn			Percn. fuzes.				Shrapnel.	Segment.	
No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.			Time and percussion.	Percussion.
									Single row of targets.			
15	10	153	15	7	122	9	7	38		15·3	17·4	5·4
									Double row of targets.			
15	8	136	15	3	11	—	—	—	6 feet apart	17·0	3·6	—
15	12	371	—	—	—	15	6	135		30·9	—	22·5
12	7	199	—	—	—	12	5	193	30 feet apart	28·4	—	38·6
									Columns of targets.			
15	11	235	15	8	273	15	13	459		21·3	34·1	35·3
15	14	648	15	14	515	15	13	543		46·2	36·7	41·7
									Skirmishers.			
15	15	47	15	8	31	15	5	11		3·1	3·8	2·2
15	12	13	15	12	18	—	—	—		1·0	1·5	—
									Skirmishers, with supports, &c.			
15	10	29	15	12	16	—	—	—		2·9	1·3	—
15	12	46	15	12	31	—	—	—		3·8	2·5	—
15	15	51	—	—	—	15	10	26		3·4	—	2·6

* Communicated by Director-General of Ordnance.

Abstract showing the average number of hits per effective round, allowing throughs, lodges, and two-thirds of the strikes to count.

12-POUNDER B.L. GUN.

Shrapnel.						Segment.						Targets.	Hits per round.			
Time fuze.			Percn. fuze.			Time & percn.			Percn. fuze.				Shrapnel.		Segment.	
No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.		Time.	Percussion.	Time and percussion.	Percussion.
15	7	14	—	—	—	15	8	32	9	4	6	*Single row of targets.*	2	—	4	1·5
												Double row of targets.				
15	8	172	—	—	—	15	9	100	—	—	—	} 6 feet apart ... ... {	21·5	—	11·1	—
15	12	435	—	—	—	—	—	—	15	9	410		36·2	—	—	45·5
15	14	438	15	15	353	—	—	—	30	25	1060	20 feet apart	31·2	23·5	—	42·4
15	7	104	—	—	—	—	—	—	15	10	217	30 feet apart	14·8	—	—	21·7
												Columns of targets.				
15	13	150	—	—	—	15	10	819	15	9	604		11·5	—	81·9	67·1
15	10	595	—	—	—	15	10	437	15	10	1050		59·5	—	43·7	105
—	—	—	9	3	185	—	—	—	9	3	268		—	61·6	—	89·3
												Skirmishers.				
15	14	46	—	—	—	15	12	42	15	7	28		3·2	—	3·5	4
												Skirmishers, with supports, &c.				
15	13	112	—	—	—	15	13	33	—	—	—		8·6	—	2·5	—
15	14	86	—	—	—	—	—	—	15	14	12		6·1	—	—	0·8
15	10	11	—	—	—	15	14	10	15	7	11		1·1	—	0.7	1·5

Taking these experiments in detail, it appears that,—

1. At a single line of targets, with boggy ground in front, the segment shell with time and percussion fuzes gave a larger number of hits per effective round than the shrapnel with the wood time fuze, but less with the percussion fuze only, as might have been expected on account of the nature of the ground.

2. At targets in double rows, 6 feet apart, the segment shell, with time and percussion fuzes, gave a less number of hits per effective round than the shrapnel with the wood time fuze. But with the segment, using the percussion fuze only, the results were slightly in favor of the segment.

At targets in double rows, 20 to 30 feet apart, the segment shell, with percussion fuze, was far superior to to the shrapnel, either with the wood time or the special concussion fuze.

3. At 6 feet targets, representing columns, the segment shell, with time and percussion fuze, produced on the whole, a more destructive effect than the shrapnel shell with the wood time fuze : the superiority of the segment, with percussion fuze only, was still more marked.

In the experiment in which special percussion fuzes were used for both shrapnel and segment shell, the segment again showed a great superiority.

4. At skirmishers without supports either in the open or in broken ground, the segment shell with time and percussion fuzes had slightly the advantage of the shrapnel ; but at skirmishers with supports and reserves, the shrapnel was more effective.

2. *Manœuvring, &c.*

Abstract showing the average number of hits per effective round, allowing throughs, lodges and two-thirds of the strikes to count.

9-Pounder.														12-pounder.										
Shrapnel.			Segment.						Targets.	Hits per round				Shrapnel.			Segment.				Targets.	Hits per round.	
			Time and percn.			Percussion.					Segment.						Time and percn.							
No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.		Shrapnel.	Time and percussion.	Percussion.		No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.			Shrapnel	Segment.
27	23	309	27	3	34	—	—	—	Single row.	13·4	11·3	—		27	10	126	27	22	47		Single row.	12·6	2·1
27	11	88	27	11	128	—	—	—		8·0	11·6	—		27	15	218	27	23	264			14·5	11·4
24	22	209	23	8	42	—	—	—	2 rows, 20 ft. apart.	9·5	5·2	—		24	14	194	24	9	57		3 rows, 30 ft. apart.	13·7	6·3
32	26	45	31	12	23	34	2	33		1·7	1·9	16·5		25	17	159	15	10	192			93	19·2
15	14	288	15	8	134	—	—	—	do. 30 ft. apart.	20·5	16·7	—		—	—	—	—	—	—		—	—	—

Taking these experiments in detail, and classifying them into single, double, and triple rows of targets, it appears that the shrapnel shell showed—against single as well as against double rows of targets—a greater average of hits per effective round than the segment shell with time and percussion fuzes, whilst against the triple rows the segment with time and percussion fuzes had, on the whole, the advantage. But with regard to the segment shell with percussion fuzes, the number of effective rounds are too few to form an average.

Abstract showing the average number of hits for every round fired, allowing throughs, lodges, and two-thirds of the strikes to count.

9-POUNDER BREECH-LOADING GUN.

Shrapnel.			Segment.						Targets.[1]	Hits per round.		
			Time and percn.			Percn. fuze.					Segment.	
No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.		Shrapnel.	Time and percussion.	Percussion.

DELIBERATE FIRING.

15	10	153	15	7	128	9	7	38	*Single row of targets.*	10·2	8·5	4·2
									Double row of targets.			
15	8	136	15	3	11	—	—	—	6 feet apart	16·9	0·7	—
15	12	371	—	—	—	15	6	135	6 feet apart			
12	7	204	—	—	—	12	5	195	30 feet apart	17·0	—	16·2
15	11	235	15	8	273	15	13	459	*Columns of targets.*	29·43	26·2	33·4
15	14	648	15	14	515	15	13	543				
15	15	47	15	8	31	15	5	14	*Skirmishers.*	2·0	1·6	0·9
15	12	13	15	12	18	—	—	—				
15	10	29	15	12	16	—	—	—	*Skirmishers, with supports, &c.*	2·8	1·5	1·7
15	12	46	15	12	31	—	—	—				
15	15	51	—	—	—	15	10	26				

MANŒUVRING.

27	23	309	27	3	39	—	—	—	Single row	7·3	3·1	—
27	11	88	27	11	129	—	—	—				
24	22	209	23	8	42	—	—	—	2 rows 9×9, 20 ft. apart.	7·6	2·8	0·9
32	26	45	31	12	23	34	2	33				
15	14	238	15	8	134	—	—	—	,, 30 ,,			

2. Manœuvring, &c.—*continued.*

12-pounder Breech-loading Gun.

Shrapnel.						Segment.						Targets.	Hits per round.			
Time fuze.			Percn. fuze.			Time & Percn.			Percn. fuze.				Shrapnel		Segment	
No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.	No. of rounds fired.	No. of effective rounds.	Effect.		Time.	Percussion.	Time and percussion.	Percussion.
DELIBERATE FIRING.																
15	7	14	—	—	—	15	8	32	9	4	6	*Single row of targets.*	0·9	—	2·1	0·6
												Double row of targets.				
15	8	172	—	—	—	15	9	100	—	—	—	6 ft. apart	20·2	—	6·6	27·3
15	12	435	—	—	—	—	—	—	15	9	410	6 ft. apart				
15	14	438	15	15	353	—	—	—	30	25	1064	20 ft. apart	29·2	23·5	—	35·4
15	7	104	—	—	—	—	—	—	15	10	217	30 ft. apart	6·9	—	—	14·4
15	13	150	—	—	—	15	10	819	15	9	604	*Columns of targets.*	10·0	—	54·6	40·2
15	10	595	—	—	—	15	10	437	15	10	1050		39·6	—	29·1	70·0
—	—	—	9	3	204	—	—	—	9	3	268		—	22·6	—	29·7
15	14	46	—	—	—	15	12	42	15	7	28	*Skirmishers.*	3·0	—	2·8	1·8
15	13	112	—	—	—	15	13	33	—	—	—					
15	14	86	—	—	—	—	—	—	15	14	12	*Skirmishers, with supports, etc.*	4·6	—	1·4	0·7
15	10	11	—	—	—	15	14	10	15	7	11					
MANŒUVRING.																
27	10	129	—	—	—	27	22	47	—	—	—	Single row	6·4	—	5·7	—
27	15	518	—	—	—	27	23	264	—	—	—					
24	14	194	—	—	—	24	9	57	—	—	—	3 rows, 6×6, 30 ft. apart	7·2		6·3	—
25	17	159	—	—	—	15	10	192	—	—	—					
16	16	240	—	—	—	15	15	66	—	—	—	2 rows, 9×9, 20 ft. apart	15·0	—	4·4	—
24	24	151	—	—	—	—	—	—	32	32	274	„ „ 30 „	6·2	—	—	8·5

General abstract of preceding tables.

	SHRAPNEL.	SEGMENT.
Rounds fired.....	619	771
Effective rounds ...	458	464
Total hits	6683	8876

Average hits per effective round.

	No. of effective rounds.	Total hits.	Hits per round.
Shrapnel with wood time.....	440	6126	13·9
Segment with time and percussion	273	3489	12·7
Segment with percussion.....	191	5387	28·2
Shrapnel with Sp. percussion fuze	18	557	30·9

Average hits per round for total practice against targets, deducting the rounds that failed to act from faulty ammunition, such as blind and premature fuzes, fuzes that blew, and shells that broke on graze.

	Rounds fired.	Faulty rounds.	Remaining.	Total hits.	Per round.
Shrapnel with wood time and percussion	619	74	545	6687	12·2
Segment with time and percussion and percussion only	771	214	557	8876	15·9
Shrapnel, wood time	595	69	526	6126	11·6
Segment, time and percussion	456	126	330	3489	10·5
Segment, percussion only	315	88	227	5387	23·7
Shrapnel, percussion	24	5	19	557	29·3

3. Field Entrenchments.

The experiments gave the following results :—

1. The advantage on the whole, appears to be with segment shell and percussion fuze.
2. In the attack of gun-pits, shrapnel with wood time fuze, was slightly superior to segment with time and percussion fuzes, in causing casualties among the detachment. Shells with percussion fuzes are best adapted for the attack of this kind of field entrenchment.
3. The existing 12-pr. and 9-pr. common shells have little value for use against earthworks.

Classification of projectiles taking—

HITS PER EFFECTIVE ROUND.

1 Segment. Percussion.	2 Common. Percussion.	3 Shrapnel. Percussion.	4 Common. Time.	5 Shrapnel. Time.	6 Segment. Time and percussion.
3·0	2·0	2·0	1·0	0·73	0·57

AVERAGE HITS PER ROUND FIRED.

1 Segment. Percussion.	2 Shrapnel. Time.	3 Common. Wood time.	4 Segment. Time and percussion.	5 Common. Percussion.	6 Shrapnel. Percussion.
0·68	0·58	0·41	0·33	0·3	0·28

4. Trials of Fuzes.

Table shewing the total number of service fuzes fired, and those that were blind, blew, or were premature.

	Fired.	Blind.	Premature.	Blew.
E time	30	—	4	—
F time	30	—	—	1
E time and C.F.S. (Freeth)	285	18	33	3
F time and C.F.S. (Freeth)	175	9	28	—
C.F.S. (Freeth)	389	45	32	—
Boxer's wood time	689	74*	1†	12

* Including the 4 fired at the bags.
† Due, most probably, to being improperly bored.

Special fuzes fired.

	No. fired.	Blind.	Pre-mature.
Elswick time, with C.F.S. (Freeth)	15	—	1
,, ,, Elswick percussion	15	—	—
Elswick percussion*	88	1	—
Boxer's percussion	69	2	—

* Two of the fuzes were purposely made to rattle to compare with those of the service pattern reported in the preceding paragraph.

Practice with time and percussion fuzes fired separately, in order to ascertain which fuze was in fault when a very large number of segment shells burst prematurely.

Fuze, and No. fired.	Fuze set to.	Mean time of burning.	Results.	
		seconds.		
F time, 15	1·4½	2·68	All good.	Fired in 12-pr. segment shells.
E time, 15	1·4	2·69	One premature.	
F time, 15	1·4	2·75	All good.	Fired in 9-pr. segment shells.
E time, 15	1·4	2·93	Three premature.	
C.F.S. (Freeth), 15	Fired in 12-pr. segment shell on graze.	12-pr. segments to act	None premature.	
Do.	Fired in 9-pr. segment shell	9-pr. segments, do.	Three premature.	

Thus E time and C. F. S. (Freeth's) percussion fuzes, whether fired separately or in combination, are not to be depended upon. With regard to the F time fuze, as all the premature explosions occurred only when it was used in conjunction with C. F. S. (Freeth) percussion, the failures may be attributed to the combination.

The practice with the special fuzes was very satisfactory, and contrasted favourably with those of the service, the only case of a premature occurring when the Elswick time fuzes were used in conjunction with the C.F.S. (Freeth) percussion.

The action of the Boxer percussion fuze in the shrapnel shell was very quick, due, no doubt, to the whole effect of the explosion of the fuze being, on account of the solid head, directed down to the bursting charge. On account of the solid head, the fuze cannot be used in conjunction with a time fuze, and the delay and difficulty of fixing it, would be grave objections to its use.

Summary of the segment, common, and shrapnel shells fired during the experiments.

SEGMENT SHELLS.

Fuze.	Number fired.		Blind.		Broke.		Premature.	
	12-pr.	9-pr.	12-pr.	9-pr.	12-pr.	9-pr.	12-pr.	9-pr.
E time and C.F.S. (Freeth)	141	144	4	14	10	8	3	30
F time and C.F.S. (Freeth)	82	84	5	4	3	14	11	15
E time	15	15	—	—	—	—	1	3
F time	15	15	—	—	—	—	—	—
Elswick time and Elswick percussion	15*	15	—	—	—	1	1	—
C.F.S. (Freeth)	188	117	11	24	19	9	4	16
Elswick percussion	40	46	—	1	13	11	—	—
Total	496	436	20	43	45	43	20	64

* C.F.S. (Freeth).

Common Shells.

Fuze.	Number fired.		Blind.		Broke.		Premature.	
	12-pr.	9-pr.	12-pr.	9-pr.	12-pr.	9-pr.	12-pr.	9-pr.
F time and C.F.S. (Freeth) ...	—	9	—	—	—	—	—	2
C.F.S. (Freeth)	68	16	10	—	1	1	10	2
Elswick percussion	1	1	—	—	—	—	—	—
Wood time.....	39	15	13	4	—	—	—	—
Total	108	41	23	4	1	1	10	4

Shrapnel Shells.

Fuze.	Number fired.		Blind.		Broke.		Premature.	
	12-pr.	9-pr.	12-pr.	9-pr.	12-pr.	9-pr.	12-pr.	9-pr.
Wood time	346	289	35	22	—	8	—	1
Special percussion (Boxer) ...	52	17	—	2	7	—	—	—
Total	398	306	35	24	7	8	—	1

Abstract of Experiments with various natures of Field Entrenchments.

1.—*Gun Pits.*

A pit is intended to give cover to one gun and its detachment, and can be thrown up by 7 men in an hour. Two pits were made, and a roughly constructed model of a field gun, and six dummies to represent the detacement, placed in each.

Experiment 1.

12-pounders. Range, 930 Yards.

SHRAPNEL.	SEGMENT.	COMMON.
Wood time fuze.	F time and C.F.S. percussion (Freeth.)	Wood time fuze.
12 rounds fired, of which— 2 blind (over), 1 fuze blew (120 yards under), 6 burst (beyond), 3 from 15 to 120 short. Result— 2 killed, 2 wounded (by same bullet). Gun and carriage not touched.	12 rounds fired, of which— 1 burst in pit, 1 beyond, 10 burst from 5 to 150 short. Result— 3 killed, 1 wounded. Gun and carriage marked by splinters.	12 rounds fired. The only shell that did damage was the 8th, which burst in the tire of gun-wheel, smashing it. Result— 2 killed, 2 wounded, One shell buried in parapet, but did not burst.

Note.—There was some little uncertainty as to the range this day.

Experiment 2.

12-pounders. Range, 1,525 Yards.

SHRAPNEL.	SEGMENT.	COMMON.
Special percussion fuze.	C.F.S. percussion (Freeth.)	C.F.S. percussion (Freeth)
12 rounds fired, of which— 1 buried in parapet, and burst; no effects, 1 passed through a thin place in the pit, and burst, 1 killed, 1 passed through the embrasure, and burst in the breast of the carriage, 1 killed, The rest broke or burst on graze with no effect. Result— 2 killed, and carriage injured.	24 rounds fired, of which— 2 were blind, 5 broke on graze, 1 was premature. Of the rest, 2 hit the parapet of the limber pit, 15 yards in rear, 1 of which broke up the dummy limber, and severely wounded the horse. The horse was also struck by splinters at round 4.* Result— Gun pit, nil, Limber pit,— Limber much injured, Horse killed.	12 rounds fired of which— 1 was premature. Of the rest, 2 burst in parapet of gun pit, and were smothered; no damage being done to parapet. Result— Nil.

II.—*Temporary Infantry Cover.*

Experiment 1.

a. Hasty trench thrown up in 18 minutes, 2′ 7″ wide, 1′ 3″ deep, for front rank kneeling, the rear rank lying down in rear (both represented by dummies). The portion fired at was about 30 feet in length, and had 15 file of dummies in it.

12-Pounders. Range, 1,525 Yards.

SHRAPNEL.	SEGMENT.	COMMON.
Wood time fuze.	E time C.F.S. percussion (Freeth.)	Wood fuze.
12 rounds fired, of which— 1 burst beyond, 11 burst in front, from 15 to 120 yards short. Result— 5 killed, 3 wounded. Of which— 3 in front rank, 5 in rear ,,	12 rounds fired, of which— 3 burst beyond. 2 buried and burst in front, 7 burst in front. Result— 2 killed, 2 wounded. Of which— 3 in front rank, 1 in rear ,,	12 rounds fired, of which— 3 blind, over, 3 burst over, 2 missed to left, clear of the men. 5 burst in front, from 50 to 200 yards short. Result— 4 killed, 1 wounded. Of which— 2 in front rank, 3 in rear ,,

Experiment 2. 12-Pounders. Range, 1,525 Yards.

SHRAPNEL.	COMMON.
Special percussion.	C.F.S. percussion (Freeth).
12 rounds fired, of which— 8 burst beyond, 3 buried and burst in front, 1 broke up, ditto. Result— Nil.	12 rounds fired, of which— 4 burst in front, Rest beyond. Result— Nil.

* The rest did no damage.

12-Pounders. Range, 1,200 Yards.

SHRAPNEL.	COMMON.	SEGMENT.
Special percussion fuzes.	C.F.S. percussion (Freeth).	C.F.S. percussion (Freeth).
2 rounds fired, of which— 1 burst on parapet after graze, 1 killed and 1 wounded, 1 hit parapet and broke up, did not burst, 2 killed, Result— 3 killed, 1 wounded.	6 rounds fired, of which— 1 burst at base of parapet, breech made 4′ wide, 1 killed, 1 burst on parapet after graze, breech made 3′ wide, 8″ deep, 1 killed. Result— 2 killed.	9 rounds fired, of which— 1 burst in parapet, breech made 2′ 6″ wide, 1′ deep, 2 killed, 1 burst over parapet, after graze, nil, 1 burst on graze 10 yards short, 1 killed, 1 blind, short, 1 broke on graze short. Result— 4 killed.* *1 by a blind shell *en ricochet*.

b. Hasty trench thrown up in 26 minutes, 4′ wide 1′ 3″ deep, for two ranks kneeling (represented by dummies) 12 file.

12-Pounders. Range, 1,200 Yards.

SHRAPNEL.	SEGMENT.	COMMON.
Wood time fuze.	C.F.S. fuze.	C.F.S. fuze.
12 rounds fired, of which— 2 burst beyond, 2 blind, 8 burst in front from 5½ to 90 short. Result— 3 killed, 3 wounded.	7 rounds fired, of which— 1 broke up, 2 burst on graze in front, 2 ,, beyond, 2 burst in the parapet, breeches 2′ wide 1′ 6″ deep, and 3′ wide 1′ deep. Result— 7 killed by the two rounds only that burst in the parapet.	12 rounds fired, of which— 4 blind,* 3 burst in or about the parapet, 2 burst on graze beyond, 3 burst on graze in front (no effects). Result— 7 killed, 1 wounded.

c. Portion of a parallel, thrown up in 1½ hours, 6′ wide, 2′ 6″ deep; intended for two ranks standing.

12-Pounders. Common Shell, C.F.S. Fuzes.

10 rounds fired, of which only one struck the parapet, making a breech 3′ wide, 1′ 6″ deep.†

Result of this shell were— 2 killed.	1 wounded. Of the rest, 6 were premature, and 3 were blind.

Opinions and Recommendations of Committee.

1. The retention in the service of the segment as a percussion shell, conditional upon a reliable percussion fuze being provided for it.
2. The introduction of the shrapnel as a time shell, to be used with the Boxer wood time fuze.
3. That in the future equipment of field artillery, the proportion of shells should be 40 per cent. of shrapnel to 60 per cent. of segment.
4. The withdrawal from the service of 12-pr. and 9-pr. common shells.

*1 of these passed through the parapet and killed 1 man.

† During this practice the vent-piece of one of the 12-pounders split in half.

5. The withdrawal of the present service metal fuzes, and experiments at once to be made in order to obtain a really reliable percussion fuze. The committee believe it to be perfectly feasible to carry shells fuzed in the limber box.

6. The black and red fuzes meet all the requirements of the service for use with the shrapnel shell. Range labels should be prepared for adjustment on the fuzes that no calculation may be necessary. A small number of fuzes for immediate use (not exceeding six) should be carried in a fuze pouch, by one of the numbers at the gun.

7. A range finder should be carried. The committee are very favourably impressed with Lieut. Nolan's instrument, and recommend further trials with it.

8. Strongly recommend the introduction of a M.L. field howitzer capable of throwing a common shell with a large bursting charge.

9. Steps should be taken to remedy the inferiority which exists in the 9-pr., when firing segment shells.

10. The committee urge the necessity of inculcating the importance of accuracy, as against rapidity of fire, for whilst it is in every way desirable to maintain celerity of movement, there can be little doubt but that deliberation in laying the gun, and in adjusting the fuze, though it may lead to a fewer number of rounds being fired in a given time, would be more than compensated for by the better result that would certainly ensue.

11. *Packing Ammunition, &c.*—The committee point out several defects of arrangement observed by them, that contribute to delay and embarrassment when a battery is first brought into action.

The ammunition boxes are much too high, rendering it difficult for any but a tall man to get shells out, one-third of their internal space is not utilized, and, in order to keep the shells in their places, it has to be partly filled up with cumbersome blocks of wood, which, from their mode of fitting, are awkward to get in and out, and liable to jam.

The necessary height required to adapt these boxes as seats for the gunners had much better be made up by folded blankets or other articles of equipment, for which at present no place is allotted, than by an arrangement which very materially affects the service of the gun.

Great objections exists in regard to the arrangements for carrying the fuzes. Two or three separate boxes have to be opened before a fuze can be got out, and they are complicated and liable to get out of order.

It would be very advantageous to increase, as far as possible, the accommodation for ammunition in the axletree boxes, so that the gun may be rendered for a time independent of its limber. A gun by itself can be rapidly intrenched, not so its limber and horses, which might in consequence have to be sent to a considerable distance to obtain cover.

Colonel Elwyn did not fully concur in the conclusions drawn from the abstracts, and submitted his views in a letter to the President, as follows :—

"1. Upon a careful analysis of the tables and abstracts of practice, and from a general survey of the results obtained, it appears to me that the segment shell has in two out of the three classes of experiments—viz., in deliberate firing and against entrenchments, shown a superiority to the shrapnel, and in the aggregate results its effects were much greater.

2. The only class of experiments in which the shrapnel showed its superiority was in the rapid manœuvres and rapid firing at unknown distances, in which the results were with both shells so unsatisfactory that they can have but little weight in showing the superiority of either. Keeping these points in view, I am of opinion that the segment shell is a most formidable projectile, that if properly manufactured and supplied with fuzes as effective as those sent from Elswick manufactory, it can

2. A detonating fuze containing 10 grains of percussion cap mixture was inserted into the perforation of a one-ounce disc of gun-cotton and fired. No explosion occurred; the gun-cotton merely burned away.

3. A detonating fuze containing 10 grains of fulminate of mercury was fired on a hank of gun-cotton thread. No explosion—gun-cotton went off in sudden flame.

4. A fuze charged with 5 grains of *pure fulminate of mercury* was inserted into the hole of a disc of compressed gun-cotton. Its explosion caused the gun-cotton to detonate violently, with very destructive effect.

5. A fuze charged with only 2 grains of fulminate of mercury was inserted, through the cork, into a bottle containing $\frac{3}{4}$ ounce of pure nitro-glycerine, which was placed on a thick plank of timber. A sharp explosion followed the ignition of the detonator, and a hole was blown in the timber immediately under where the bottle rested.

6. A similar bottle of nitro-glycerine, fitted as above, was placed on a $\frac{1}{4}$ lb. disc of gun-cotton. The nitro-glycerine exploded, but simply scattered the gun-cotton, portions of which were inflamed.

7. An ounce of gun-cotton fitted with a 5 grain mercury detonator, was fired alongside a $\frac{3}{4}$ ounce bottle of nitro-glycerine. The latter was detonated by the explosion of the gun-cotton.

The above experiments demonstrate that an explosive mixture, such as percussion cap composition, will not detonate gun-cotton even if used in considerable quantities, whereas a charge of 3 grains of the same composition is sufficient to detonate nitro-glycerine.

They also showed that it is necessary for the gun-cotton to be in a compressed condition, and that a particular *kind* of detonation must be produced, in order to ensure the detonation of the gun-cotton.

The following experiments illustrate the force of gun-cotton as compared with gunpowder, when the former is ignited by a proper fulminating fuze:—

8. A cylindrical paper cartridge, 9 inches long by 1 inch in diameter, was filled with ordinary gunpowder (5 oz.), and inserted in a hole bored in an upright timber balk 12 inches square. The powder fired with a puff, slightly splitting the wood.

9. A similar cartridge filled with gun-cotton (4 oz.), was inserted in a similar balk. The gun-cotton detonated with a loud explosion, and the balk was cut off level with the ground.

10. A stockade was formed of four wooden balks, each 12 inches square, let into the ground about 2 feet 6 inches, and well strutted behind.

A 1 lb. disc of gun-cotton was placed in the centre of each balk, the intervals being filled with $\frac{1}{2}$ lb. discs (10); thus all the discs were touching.

One of the extreme discs was fired by a detonating fuze, when the whole exploded with great violence, cutting down the stockade level with the ground, and hurling the pieces all round.

11. A 1 lb. disc of gun-cotton was detonated on a block of stone 2 ft. × 3 ft. × 1 ft. 3 ins. The stone was blown into powder.

12. A 9 inch cast-iron cylinder of 250 lbs. weight, was drilled with a $1\frac{1}{2}$ inch hole in the centre, and a charge of $4\frac{1}{2}$ ounces of gun-cotton inserted, the hole being left quite open at the top. The cylinder was placed in a pit about 2 feet deep in the ground, and the charge detonated. The cylinder was blown into many pieces, which were subsequently found embedded in the sides of the pit. The base of the cylinder was driven into the ground to some depth.

75. DESCRIPTION OF A SCALE TO BE ATTACHED TO INSTRUMENTS FOR FINDING THE DISTANCES OF SHIPS AT SEA FROM ELEVATED COAST BATTERIES.*—The problem of finding the distance of a ship at sea from an elevated coast battery, is one of easy solution; for (supposing the height of the battery above the sea level to be known), a single observation with a suitable instrument to find the depression of the water line of the ship, gives the necessary data from which the range can be found by a simple calculation.†

This simple calculation (for obvious reasons) presents a difficulty, which has generally been overcome by resorting to one of two methods, viz. :—

(1) The instrument for finding the depression is graduated for ranges for only one elevation above the sea.
(2) A table is provided in which calculated ranges are placed opposite to various elevations and various angles of depression.

Each of these methods has its disadvantages. In the first, the scale is only of use for one elevation above the sea, and is useless if taken to any other, greater or less. Even if it always remain in the same place, it cannot always give exactly true results, as the height of the battery above the sea level varies with the rise and fall of the tide.

In the second method only an approximation can generally be obtained, as it is manifestly impossible to write down all angles of depression and all elevations above the sea.

The difficulty caused by the calculation may probably be overcome by using some such scale attached to the instrument as is described below. By means of such a scale (adjusted for the height of the battery previous to making the observation), the range can be read off exactly and immediately, without any calculation or reference to tables.

The scale described below, is one to be attached to the tangent scale of Bell's

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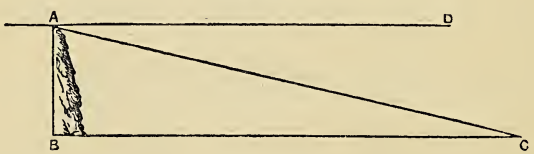
* By Lieut. G. Mackinlay, R.A.

† This is evident from the following considerations. (See Fig. 1). Let AB represent the height

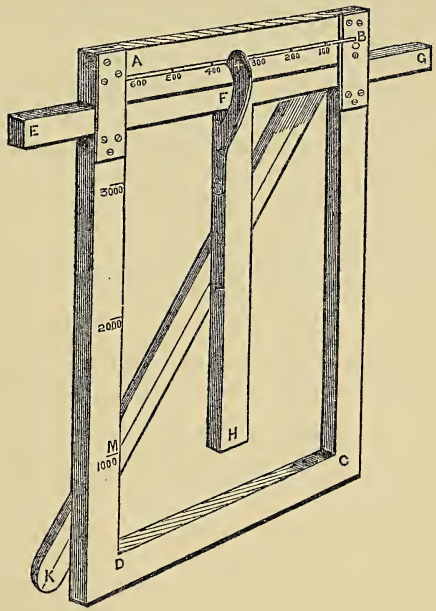
Fig. 1.



of the battery (which is known), C the distant ship, floating on BC, the surface of the water. Join AC, through A draw AD horizontally. Then if we find the angle DAC by observation, we can solve the right-angled triangle ABC, since the angle DAC equals the angle ACB, and then we can find BC the range.

hydroscope,* but the principle involved admits of similar scales being adapted to all instruments for measuring angles of depression.

Description of Tangent Scale.—*FH* is a tangent bar with a cross piece *EG* rigidly fixed at right angles, so that the two together form a sort of T square. (See sketch).



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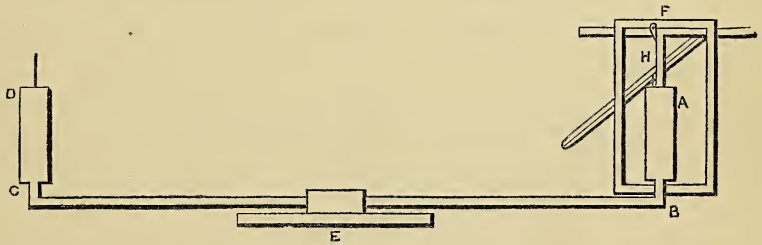
* Bell's hydroscope consists of a long pipe *BC*, connecting two small cisterns *AB*, *CD*. (See sketch). The pipe is supported in a bed *E*, and when required for use is placed nearly horizontally.



The cisterns are partly filled with water, and two floats (exactly similar), are placed, one in each cistern. The tops of these floats are then in the same horizontal line.

The side of the cistern *AB* carries a brass holder, in which a tangent scale *FH* (with a sight at top) slides up and down. (In the sketch the brass holder is on the other side of *AB*, and the tangent scale is the one about to be described).

The observer stands by the cistern *AB*, and moves the pipe and tangent scale until the sight, the top of the float in *DC*, and the water line of the ship observed, are in the same line.

The length of tangent scale is then indicated on *FH* by the top of the float in *AB*.

FH carries at its top a piece of brass *F*, fixed at right angles to the plane of the T square. This piece of brass is pierced with a cross-sight hole, and forms a pointer.

On *EG* slides the rectangular frame *ABCD*, to which is attached an arm *BK* (pivoted at *B*), capable of sweeping over all the back of the frame.

The top of the frame *BA* (from *B* where *BK* is pivoted, to *A*, the prolongation of the interior edge of *DA*), is graduated regularly from 0 to 600 feet.*

The interior edge of *AD* is graduated as for a tangent scale for an instrument 600 feet above sea level.

To use the Scale.—Suppose we are in a battery 373 feet above sea level. Slide the frame over *EG* until the pointer *F* points to 373 on the scale *BA*.

Place *FH* in the holder of the hydroscope, make the observation, and suppose *FL* the length of tangent scale indicated on *FH*. Move the arm *BK* until its centre line coincides with *L* on *FH*. Then read off the range on *AD*, as indicated by the centre line of the arm.

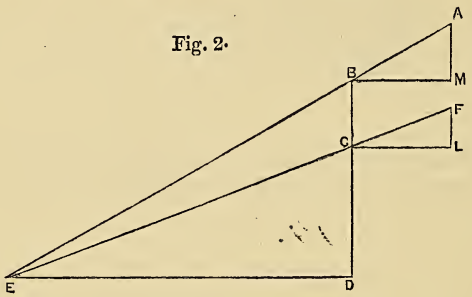
The arm in the sketch points to a range of 1000 yards. Similarly, the range can be found from a battery at any elevation, by adjusting the frame previous to taking the observation.

Proof.—Let *F* be set to any number *n* (less than 600). Then by the construction of the scale we have this relation (see sketch of instrument):—

$$FL : AM :: n : 600.$$

Let *BAM*, *CFL* (see Fig. 2), represent the hydroscope in two different positions—

Fig. 2.



on a cliff *BD* 600 feet high, and on a cliff *CD* *n* feet high—*AM*, *FL* being the lengths of tangent scale in each case for the same distant ship.

Let *E* be the distant ship on the water *ED*. Join *AE*, *FE*. Then we have, by similar right-angled triangles, the same relation as before given by the scale—

$$FL : AM :: CD : BD :: n : 600.$$

Conversely, when this is the case, *FL* and *AM* both refer to the same range.

Therefore the range read off on *AM* (in the scale) is the true one for *FL*.

A scale similar to the above has been made at Dover, and when used with a hydroscope gave good results.

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* 600 feet are taken, as it is assumed that no battery is more than 600 feet above sea level. More or less might be taken.

be used either as a time, or as a percussion shell to greater advantage than the shrapnel; and that it is much better adapted for the general requirements of war in which the attack of villages, entrenchments, stockades, &c., must be included.

3. The segment shell should never be used with two fuzes; in most cases the percussion fuze will be found best suited for it, and this should be considered as its ordinary fuze; but when the ground is unfavourable to the action of the percussion fuze, the time fuze should be substituted for it. The employment of the two fuzes at the same time seems to lead to no good result, whilst it causes delay in serving the guns, and adds unnecessarily to the expense of the projectile. The F fuze, which acted well as a time fuze, is also a percussion fuze; but this double action appears to me to be objectionable, and it adds greatly to the expense.

4. The cost of the segment shell is less than half that of the shrapnel, but the fuzes used with it are much more expensive than those used with the shrapnel; but if one fuze only is used at a time with the segment, its total cost will be far less than that of the shrapnel.

5. The shrapnel shell has proved itself to be a very valuable projectile as a time shell, and in some cases superior to the segment shell; and if it should be considered desirable to introduce it into the service for the 12-pr. and 9-pr. rifled guns, in consequence of any difficulty in providing a suitable time fuze for the segment shell, the proportion of one-fourth would in my opinion be sufficient.

6. The time fuze supplied with the shrapnel shell is perfectly safe, but a very considerable number were blind.

The service E time, and the C.F.S. (Freeth) percussion, fuzes for the segment shells are altogether unreliable and unsafe, and should be no longer retained in the service. Steps should therefore be taken to provide proper fuzes for the segment shells, and to ensure that the construction of the shell shall in future be more in conformity with the design of the inventor than appears to be the case.

7. The unsatisfactory practice at unknown ranges whilst manœuvring rapidly, shows that a large quantity of ammunition may be wasted without the fact being observable from the battery, and points to the necessity of some means being provided for ascertaining in the field, and within reasonable limits, the distance of the object to be fired at. For this purpose an instrument, invented by Lieutenant Nolan, R.A., was fitted to two guns of the 12-pr. battery; it was worked by the gun detachments, under Lieut. Nolan's instructions, and the ranges were measured with sufficient accuracy in about one minute and a-half, or during the time which a field battery must take to come into action, and get ready its ammunition for firing. This was the only instrument submitted to the committee; and they were so favourably impressed with it that they recommended its further trial.

Should this or some other instrument for the purpose be introduced into the service, the fullest advantage might be obtained from the guns of precision of the present day, an advantage which was signally lost in the rapid manœuvres at Dartmoor, where the peculiar features of the ground made it most difficult to ascertain the ranges by means of trial shots."

73.

Captain W. H. Noble, R.A., 6. 1. '70, submits the following Electro-Ballistic experiments for record:—

Nature of Gun.	Calibre.	Length of bore in calibres.	Charge.	Projectile.			Mean initial velocity.
				Nature.	Mean weight.	Mean diameter.	
	ins.		lbs.		lbs.	ins.	ft.
12-inch M.L. of 25 tons.	12·0	12·0	67	Palliser.	600	11·92	1180
"	"	"	67	Com. shell.	495	"	1271
"	"	"	50	Com. shell.	"	"	1140
10-inch M.L. of 18 tons.	10·0	14·5	60	Palliser.	400	10·92	1298
"	"	"	40	Com. shell.	"	"	1117
9-inch M.L. of 12 tons.	9	13·9	43	Palliser.	250	8·92	1336
"	"	"	30	Com. shell.	"	8·92	1192
8-inch M.L. of 9 tons.	8	14·8	30	Palliser.	180	7·92	1363
"	"	"	20	Com. shell.	"	7·92	1165
7-inch M.L. of 7 tons.	7	18·0	22	Palliser.	115	6·92	1458
"	"	"	14	Com. shell.	"	6·92	1258
7-inch M.L. of 6½ tons.	7	15·9	22	Palliser.	115	6·92	1430
"	"	"	14	Com. shell.	"	6·92	1230
64-pr. M.L. of 64 cwt.	6·3	15·6	8	Com. shell.	64	6·22	1170
7-inch B.L. of 82 cwt.	7	14·2	10	"	110	7·09	1013
"	"	"	11	"	90	7·09	1165
64-pr. B.L. of 61 cwt.	6·4	10·9	9	"	64	6·48	1200
40-pr. B.L. of 35 cwt.	4·75	22·4	5	"	41	4·8	1180
20-pr. B.L. of 16 cwt. (land service.)	3·75	22·4	2 lbs. 8 ozs.	"	21	3·8	1130
20-pr. B.L. of 13 cwt. (sea service.)	3·75	14·5	"	"	"	"	1000
12-pr. B.L. of 8 cwt.	3·0	20·5	1 lb. 8 ozs.	Segt. shell.	11·75	3·07	1170
9-pr. B.L. of 6 cwt.	3·0	17·7	1 lb. 2 ozs.	"	9·25	"	1057
7-pr. M.L. mountain, steel, of 150 lbs.	3·0	8·0	6 ozs. F.G.	Com. shell.	7·2	2·94	673

74.

Captain W. H. Noble, R.A., 19. 2. '70, submits for record, the following account of some experiments which were carried out in the Royal Arsenal, Woolwich, last summer, to illustrate the differences which exist between gun-cotton and nitro-glycerine as regards their susceptibility to explosion from the effects of detonation. These trials further exhibit the enormous force of gun-cotton, when exploded by detonation, as compared with that of ordinary gunpowder.

1. An electric fuze charged with 100 grains of a mixture of sulphide of antimony and chlorate of potash, was placed on a quarter pound disc of compressed gun-cotton, and fired by the magneto-electric machine. No explosion occurred. The gun-cotton merely ignited and burned out with the usual yellow flame.

76.

The following is an abstract of the recent preliminary report by the Committee on Explosives, 5. 2. '70:—

In the Memorandum of Instructions furnished to the committee, their attention was specially directed to "the importance of an early determination of the description of gunpowder whose employment in large charges is attended with the least risk of over-straining the guns," and they were desired to report progress from time to time on this part of the question.

The committee have, therefore, up to the present time, given their attention specially, and almost exclusively, to this branch of the enquiry entrusted to them.

They consider that sufficient progress has now been made in the experiments bearing upon this subject which have been carried on with the 8-inch M.L. gun, to show that there is no difficulty in producing a description of powder much better suited for use in guns of large calibre than the present service powders.

In investigating the action in the gun of the above descriptions of gunpowder, the committee have availed themselves of the following means, namely:—

a. The determination of the time a projectile takes to traverse various intervals within the bore of a gun. This was accomplished by means of a chronoscope designed to measure very small intervals of time.

b. The determination of the pressure, directly, by means of Rodman's pressure gauge, fitted on the exterior of the gun and communicating with the interior of the bore by means of a hollow screw plug.

c. The determination of the pressure, directly, by means of a new form of inner gauge, termed a "crusher," designed expressly for the committee.

With a view of investigating the influences exerted by the chemical and physical characters of the different descriptions of gunpowder, upon the results furnished by them as regards velocity and pressure, each variety has been submitted to complete analysis and to a determination of density by means of the mercury-densimeter.

The Chronoscope.—The principle of action of this instrument consists in registering, by means of electric currents upon a recording surface travelling at a uniform and very high speed, the precise instant at which a shot passes certain defined points in the bore.

It consists of two portions; firstly, the *mechanical arrangement* for obtaining the necessary speed, and keeping that speed uniform; secondly, the *electrical recording arrangement.*

The "Rodman" Pressure Gauge."—This gauge is so well known that the committee have considered it unnecessary to do more than give a very brief description of it.

The extreme variability of the results given with this instrument led them to devise a modified form of the pressure gauge, in which some of the causes of error inherent in the "Rodman" gauge were eliminated.

The "Crusher" Gauge.—This apparatus was made in the Royal Gun Factories at the suggestion of the committee. It consists of a screw plug of steel, provided with a movable base which admits of the insertion of a small copper cylinder in a chamber. One end of this cylinder rests on an anvil, while the other is acted upon by a movable piston, which is kept tightly against the cylinder by means of a spring. The cylinder is centred in the chamber by a small watch spring.

The action of the apparatus is as follows:—

Upon the explosion of the charge, the gas, acting on the area of the piston, crushes the copper cylinder against the anvil. The amount of compression which the copper thereby sustains becomes an indication of the pressure. The area of the copper cylinders found most suitable with the 8-inch gun was $\frac{1}{12}$ of a square inch, while the area of the piston was $\frac{1}{6}$ of a square inch.

A series of experiments having been made by means of a testing machine to determine the pressure required to produce a definite amount of compression in copper cylinders corresponding to those used in the instrument, the tabulated results furnished a means of comparison whereby the amount of compression produced in the "crusher" becomes a direct indication of the pressure at that part of the bore where the plug is inserted.

The committee found that much greater dependence could be placed upon the results furnished by this apparatus than upon those obtained with the "Rodman" gauge.

The Gun and Projectiles.—The gun employed in the experiments now under discussion was an 8-inch wrought-iron muzzle-loading gun of $6\frac{1}{2}$ tons, having a length of bore of 126 ins.

It was tapped at three places in the powder chamber, to receive either "Rodman" or "crusher" gauges. These holes could be closed with solid plugs when not required. The cutting plugs belonging to the chronoscope were fourteen in number, and were fitted into holes at various intervals along the bore. When not required, those holes were closed with solid plugs. With a 20 lbs. charge, and a shot 15 ins. in length, the projectile, when rammed home, was flush with the edge of No. 1 plug. When battering charges were used, the projectile was flush with No. 2, which then became the first plug of the series.

Six cutting plugs were used in each observation, those of the breech and those of the muzzle being alternately employed. The projectiles used were cast-iron cylinders of 15 ins. in length, 180 lbs. weight, and 7·975 ins. diameter.

The loading of the gun was conducted as follows:—

The cartridge was made up to the full diameter of the bore; it was then inserted into the shot chamber, the projectile was next pushed home gently until a stop on the rammer came into contact with the face of the muzzle; thus, the head of the shot was brought to the same position in each round, and the cartridge always touched the base of the projectile.

The "Rodmans," "crushers," and cutting plugs were then inserted into their respective holes and screwed home.

Finally, the wires of the cutting plugs were connected with the main wires leading to the instrument, and the tube inserted in the vent.

After the discharge, the first operation was to wash out the gun; all the plugs were then removed, and the holes dried preparatory to another round.

The coppers were taken from the "Rodmans" or "crushers," stamped with the number of the round, and the measurements recorded.

From the various descriptions of powder which have been experimented with, up to date, four kinds have been selected for the purpose of this preliminary report, as furnishing good illustrations of the different results obtained with battering charges of different kinds of powder; these are:—

(1) R.L.G. service powder,
(2) Pellet service powder,
(3) Russian prismatic powder,
(4) Pebble powder No. 5,

The velocities and pressures given by these powders are shewn in the following table:—

Table shewing the velocity and maximum pressure per square inch given by four different descriptions of powder, fired with shot of 180 lbs. in the 8-inch gun, Expl. No. 288.

Nature of powder.	Charge.	Muzzle velocity.	Maximum pressure.
	lbs.	ft.	tons.
R.L.G.	30	1324	29·8
Russian prismatic	32	1366	20·5
Service pellet	30	1338	17·4
Pebble, No. 5	35	1374	15·4

The first example given above represents R.L.G. powder of 1·67 density; the committee have found, however, that there is a very great want of uniformity in the service R.L.G. and L.G. powders at present in store, as evidenced by differences in the densities which range between 1·60 and 1·78.

A powder having a density of 1·745 has also been tried; it gave, with a 30 lbs. charge, a velocity of 1350 ft., and indicated a maximum pressure of 23 tons per square inch.

A careful consideration of the results hitherto obtained with the form of powder termed "pebble," and the circumstance that the production of such a powder involves little departure from the existing system of manufacture, have led the committee to decide that they are justified in recommending the provisional adoption (and the manufacture to such an extent as may be at present required for the supply of all heavy guns of 7-inch calibre and upwards) of a "pebble" powder made according to the following specification:—

"The powder to have a density of 1·80 (the limits of manufacture being 1·78 and 1·82), and to be produced by breaking up "press-cake" of the specified density into lumps, which are retained between sieves of $\frac{5}{8}$ and $\frac{4}{8}$ in. mesh respectively. The lumps to be afterwards submitted to the ordinary processes."

The committee consider that, in the event of the provisional introduction of "pebble" powder, steps should be at once taken to ascertain the charges of this powder required to obtain velocities equal to the standard velocities of the several heavy guns.

The committee have already reported that the employment of the description of powder now recommended will not entail any alterations in the dimensions of the present pattern metal cases.

In confining themselves to a recommendation that the charges of the new powder for heavy guns should be proportioned to give velocities equal to those obtained with R.L.G., the committee think it right to point out that, in addition to the reduction in maximum pressure obtained by the use of "pebble" powder, or such powder of similar properties as may be finally adopted, there is a probability that another important advantage will be secured—namely, the attainment with safety of a considerable increment in velocity with heavy guns, whereby a material increase will be effected in the power of our armament.

It is anticipated that definite and conclusive information on these important points will be furnished by the experiments with the 10-inch gun which are now in progress.

77.

Memorandum, dated 12. 7. '70, relative to the progress of experiments by the Committee on Explosives since the preliminary report submitted to the Secretary of State for War in February, 1870 :—

10-*inch Gun.*—The experiments of the committee since the above date have chiefly consisted in observing the effects of various kinds of powder, fired from a 10-inch gun, in a similar manner to those fired from the 8-inch gun (as described in the preliminary report).

A chronoscope constructed with eight discs has, however, been brought into use in place of the one with six discs, and observations of the velocity outside the muzzle have been taken with the Navez-Leurs apparatus. The committee have therefore obtained, in every round fired from the 10-inch gun, three different and independent series of indications of the action of the powder, viz. :—

(1) The times occupied by the shot in passing over eight known intervals within the bore of the gun, by means of the eight revolving discs of Captain A. Noble's chronoscope.

(2) The velocity outside the bore at a distance of 50 yds. from the muzzle, by the Navez-Leurs chronoscope.

(3) The pressure exerted by the gas at various points of the bore (usually five in number), as indicated by the crusher gauges described in the preliminary report.

The pressures have also been calculated, as before, from the various rates of movement in the bore indicated on the Noble chronoscope, and it has been highly satisfactory to find that all the observations of pressure and velocity thus independently taken, have corroborated and confirmed one another in a remarkable degree, with the exception of certain discrepancies as regards pressure, which have been confined to quick-burning powders, and which the committee hope to explain in their detailed report.

In several instances copper cylinders that have been compressed in the crusher by one round, have been used a second time to ascertain whether they would undergo further compression, and thus to learn to what extent the explosion of the charge acted like a blow on the gun. The importance of obtaining data on this point was strongly urged by the Superintendent Royal Gun Factories. The experiment has been tried ten times, in four of which the velocity was greater on the second occasion, and a further slight compression necessarily resulted. In three cases of the remaining six there was no alteration; in two cases one of the crushers showed a slight change. The only instance in which the crushers were decidedly more compressed without the velocity being increased, was in firing R.L.G. (the quickest powder used) with a rear axial vent.

The committee have now fired 97 rounds from the 10-inch gun with projectiles of 400 lbs. weight, and charges varying from 60 lbs. to 70 lbs. of powder, of different kinds and different degrees of density.

	Charge.	Rounds.
	lbs.	
R.L.G.	60	28
Pellet	64 to 70	20
Prismatic, Russian	61 and 68	7
" Ritter's	61 " 70	7
Pebble	70	33 } 35
"	60	2 }
Total	.....	97

The most favourable results hitherto obtained have been with a pebble powder having a density of 1·732, and grains of uniform size; 70 lbs. of this powder gave an average velocity exceeding by 150 ft. per second the average velocity with 60 lbs. R.L.G., whilst the maximum pressure indicated by the crusher gauges was only three-fifths as much. A single round of 60 lbs. of this powder gave 40 ft. more velocity than 60 lbs. R.L.G., with only two-fifths of the pressure, as indicated by the crushers.

The principal average results, in various series of 6 rounds each, are shown in the following abstract, the pressures given being the highest, as indicated by the crusher gauges :—

Nature of powder.	Density.	Charge.	Velocity.	Pressure (tons per square inch.)	Remarks.
		lbs.			
R.L.G.	1·742	60	1318	51	
	1·733	60	1321	48	
	1·67	60	1313	53	
Pellet	1·677	64	1364	25	
Prismatic, Russian	1·66	61	1335	19	
		68	1425	29	One round.
" Ritter	1·66	61	1349	21½	
		70	1416	24	One round.
Pebble	1·732	70	1474	29	Uniform grain.
	1·782	70	1432	21	
	1·732	60	1359	21	One round.
	1·782	60	1298	15	One round.

All the working arrangements connected with this gun have answered well, and are still in good order. The committee hope to terminate, shortly hence, the experiments they think desirable to make with it in the smooth-bore state, and then to have it rifled with a view to a further course of trials.

8-inch Gun.—With this gun, which was used for the experiments described in the preliminary report, the committee propose to fire a series of rounds with projectiles varying in weight from 170 lbs. up to 200 lbs. (those hitherto used having been 180 lbs.) before rifling it, and then to repeat the experiments with projectiles and powder of exactly the same nature and quality. These trials have been begun, but are at present suspended in consequence of the giving way of one of the trunnions which had been lengthened in order to adapt the piece for being mounted on the carriage belonging to the 10-inch gun. They will be resumed in a few days.

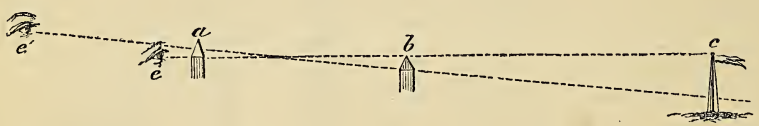
Application of Gun-cotton to Small-arms.—The proceedings of the committee in this branch of the enquiry have been confined to a few tentative trials with gun-cotton cartridges, modified in various ways, to obtain velocity and regularity equal to what are given by the service cartridge.

Experiments in progress.—In addition to the experiments above mentioned, the committee propose to fire pebble powder from the 7-inch, 8-inch, 9-inch, 10-inch, and 12-inch rifled guns at Shoeburyness, with a view to determining the proper charges of that powder for those pieces.

They have also prepared an arrangement for introducing crusher gauges into the base of the shot, in order to get a direct indication of the pressure exerted on the projectile as well as on the gun.

78. The line of sight employed in laying field guns. Communicated by Captain J. R. Oliver, R.A.

It has been repeatedly noticed as a curious fact that field guns give greater or less range for the same apparent elevation according as they are laid with the eye at some little distance from the tangent sight, or close up to it; and it has been found by actual experiment at Aldershot with the breech-loading 9-pr., that a difference of 3 ft. in the position of the eye makes a difference of about 150 yds., more or less, in the range of the projectile. Again, if we lay a gun carefully on some object in the ordinary manner—that is, with the eye close to the notch in the tangent sight—and then step back two or three feet, we shall always find that from the new position the gun appears to have been laid low—the straight line that (as we think) joins the eye, the notch, and the trunnion sight, passing below the object; and the farther we step back, the greater will be the apparent difference. That this is really the case, any one may easily satisfy himself by making the experiment. The explanation is as follows:—



Let *a* represent a section through the tangent sight, *b* the same through the trunnion sight, *c* the object—the top of a flagstaff for instance—*e* and *e'* the two positions of the eye. The respective lines of sight are indicated by the dotted lines, the figure having been purposely distorted to show the effect of change of position more clearly.

When the eye is close to the notch, the object can be seen through it, and there is little difficulty in bringing the point of the trunnion sight into the straight line joining the eye and the object. But when the eye is withdrawn a few feet, the notch looks very small; in fact, it becomes impossible to see *through* it, and we are compelled—perhaps without being aware of it—to view the object *over* the top of the tangent sight. At this distance the apparent size of the trunnion sight is also much diminished, and we are obliged to see *more of it* to see its tip at all. In other words, we now use a higher point of the tangent sight and a lower point of the trunnion sight for our line of sight, which, as a necessary result, will pass below the object, as shewn in the figure. It follows that, if we lay a gun with the eye some little distance from the tangent sight, we must give less elevation than when using the ordinary method.

79. Abstract of a report of an experiment carried out at Colombo, by Colonel Cox, Commanding Royal Artillery, Ceylon, to determine the penetration of round shot.

The fort of Colombo, originally constructed by the Portuguese in 1520, was rebuilt by the Dutch about 1660, who surrendered it to the English in 1796, without firing a shot.

The works were in a very good state of preservation. It has lately however been decided that the ramparts should be pulled down.

Colonel Cox considered that the occasion ought not to be lost, as a means of instruction and gaining experience for both officers and men, and obtained authority to establish a breaching battery opposite the face of one of the bastions.

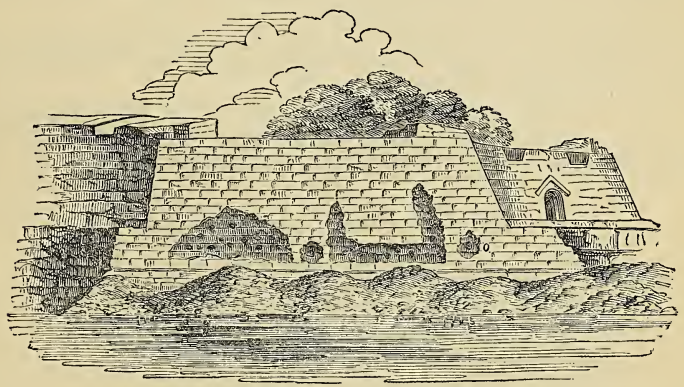
The escarps are strongly riveted with large blocks of stone, locally called cabook. It is of a deep red colour, and appears to be decomposed gneiss. It is soft when cut from the quarry, and hardens by exposure, but it is a tough rather than a hard stone.

Owing to the nature of the ground, the breaching battery was placed at 63 yds. from the escarp. Some uncertainty being felt as to what the effect of the splinters at that distance might be, and as a space had to be levelled on the crest of the glacis to lay down temporary platforms for the guns, a slight parapet about 3 ft. thick, with embrasures for the guns, was formed of cabook.

The work of throwing up the battery and laying down the platforms, was performed by Lieut. Legge, R.A., with the gun Lascars under his command.

In laying down the battery, the crest of the glacis was levelled so as to form a terreplein for the guns, and, as the soil was loose and sandy, cabook stone was laid upon it, then broken up into small pieces, mixed with sand soaked with water, and well rammed until the whole formed a compact mass, with the required slope to the front. The cement thus formed, after being thoroughly baked by the rays of a tropical sun, by the following evening presented a firm and smooth floor for the guns.

The practice at the escarp commenced at a quarter to five on the evening of the 29th December, 1869. The men were kept under cover in rear of the battery until it was ascertained from the first few shots that no danger need be apprehended from splinters. The cabook being strong and tenacious, the shot penetrated it like a very hard cheese. The practice commenced by marking out the extent of



the breach on each side, by shots from the right and left guns; and it was then intended to cut a horizontal line towards the centre from these two extreme points, and afterwards to cut perpendicular lines up the face; but it was soon seen that the number of rounds of shot was not sufficient to allow of this being done. Colonel Cox therefore allowed Lieut. Legge, who commanded the two left guns, and Captain Tweedie, who had the two right guns, each to direct their fire as they thought best to produce the greatest effect with the number of rounds that remained. The penetration of the shot was very considerable; but the great thickness of the walls, and the tough and tenacious nature of the material, presented a most formidable resistance to the effect of the shot, which had very little shattering effect. It is evident that cabook is well adapted for permanent fortifications. It is extremely durable: these escarps, built about 200 years ago, are in perfect preservation. It is more easily worked than stone, and splinters very little; and

if covered with cement—as was done by the Dutch engineers—does not weather. There is said to be much cabook—also called laterite—on the continent of India; it may therefore be of importance to Engineers to know something of its capabilities as tested on this occasion. The fire was directed rather higher up on the escarp than usual, as it was necessary to fire above a line marked by the Engineers as the future level of the ground.

The guns employed were one 24-pr. of 50 cwt., and three 18-prs. of 42 cwt. The greatest penetration of shot striking the wall where the surface was not previously broken was—

24-pr.	4 ft.
18-pr.	4 ft. 2 ins.

The depth of the breach was about 3 ft. at the apex. The greatest depth to which any shot had reached was 5 ft. 7 ins. The height of the escarp was about 38 ft. The embrasures at the top of the escarp had been removed previous to the practice, and part of the *débris* shewn at the foot of the wall arose from their removal. The revetment was about 15 ft. thick at the place where it was partially breached. The total number of rounds of ammunition expended was forty-eight, being twelve from each gun.

80. Demolition of No. 37 Martello Tower by Gun-cotton. May 31, 1870. Communicated by Captain W. H. Noble, R.A.

The Martello tower No. 37, situated on the Sussex coast between Hastings and Winchelsea, was selected for this experiment.

This tower was at the time uninhabited, the upper floor and woodwork having been destroyed during the experiments in 1866, in connection with Gale's protected gunpowder (O.S.C. Report 4258).

The tower was similar in dimensions to those tried at Eastbourne, 1860, and Bexhill, 1861. It was of brick, and is said to have been built about 1803–4, at a cost of £3,000. The following were the principal dimensions:—

	ft.	in.
Diameter at top	40	0
„ foot	46	0
Height	32	6
Inside height to vault	18	6
Thickness, sea front	12	6
„ land front	7	0
„ over crown of vault	5	0
Diameter of internal central column supporting the vault	4	6

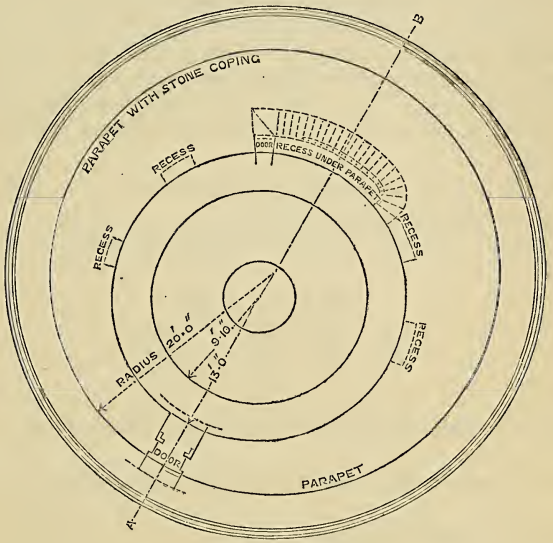
The roof of the tower was supported by a bomb-proof vault, held up in the centre by a pillar 4 ft. 6 in. in diameter. In appearance, the tower was perfectly sound, with the exception of some slight cracks in the brick-work of the central pillar, caused it is presumed by the heat of the previous fire. The tower was designed for one gun, accommodation for about twenty men, and magazine room for some eighty barrels of powder. Altogether, the whole structure may be said to have been of considerable solidity.

The gun-cotton (200 lbs.) was arranged in three equal charges, laid without tamping on the basement floor, one charge being within the small magazine. The charges were exploded simultaneously by means of electric detonating fuzes (30 grs. fulminate), the firing party being at about 300 yds. from the tower.

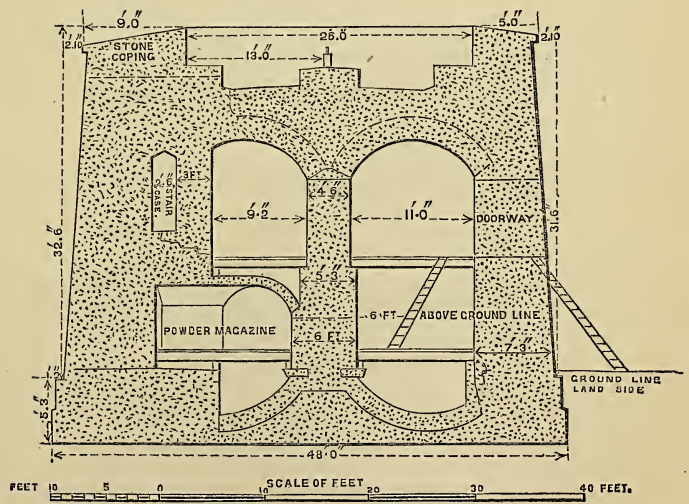
Looked upon as a work of demolition, the effect was very satisfactory. The bomb-proof roof, at the moment of explosion, appeared to rise about 2 ft. in the air; the walls fell outwards, as if hinged at the bottom, and the roof dropped

into the centre of the *débris*. The explosion was not characterised by the sharp report usual to gun-cotton, and the splinters were not thrown to a greater distance than 50 yds. The diameter of the chief *débris* was about 90 ft.

The most remarkable feature of this experiment, was the ease, rapidity, and safety with which the work was performed. There was no previous preparation, no sinking shafts, tamping charges, &c., &c. The Engineer Committee brought a few boxes of gun-cotton, a few hundred yards of copper wire, and a small frictional machine. In about an hour after their arrival, the tower was a heap of bricks and rubbish.



Plan of the top of the Tower.



Elevational Section on the Line *AB*.

81. Pocket Sextant. Communicated by Captain R. O'Hara, R.A.

The value of the pocket sextant as an instrument for military sketching, seems to be very much overlooked; and yet, in comparatively open ground, it is far superior to the prismatic compass. With its assistance, a tolerably accurate sketch of country can be made from one high piece of ground, giving approximate differences of level; also, by means of empirical formula, it can be used to find ranges, &c., without the use of tables, fixed angles, or fixed bases (of course, with a fixed base, the work is a little simplified). One person can obtain the required result without assistance, which is an advantage of some importance. The principle of finding distances, &c., is the old one, of a right-angled triangle, as shewn in the "Handbook for Field Service," 1854, p. 144. In a triangle ABC, the angle at B being the right angle, AB the distance to be found in yards, BC the known or measured base in feet. Then $BAC = (90 - BCA)$ may be called the angle of depression, which it would be if BC was a vertical height.

Let $S = 11{,}459$,
$D = BA$ = distance in yards to be found,
$H = BC$ = base (or height) in feet,
M = number of minutes in angle of depression = $(90 - BCA)$.

Empirical Formula.

$$\text{Then } D = \frac{HS}{10M} - \frac{MH}{30{,}000}.$$

$D = \frac{HS}{10M}$ is, I think, sufficiently accurate for artillery practice.

With pocket sextant, to find angle of depression from a height:—

(1) By means of natural horizon.

Measure the angle between the object and the horizon, and apply correction for dip. This correction may be obtained by empirical formula also, viz.:—

$\frac{5}{9}$ square of distance in miles = height of station in feet;
$\frac{4}{5}$ distance in miles = correction for dip in minutes.
Or $\sqrt{\text{height of station in feet}}$ = correction for dip in minutes.

This latter is not quite so correct.
In the first of these, the height of station being known, distance in miles may be obtained, and from this the correction for dip.

(2) Without horizon.

Suspend a plummet by suture silk from screw fastening index arm. The angle between this and the object will be the complement of the angle of depression.
N.B.—If there is wind, suspend the plummet in water.

(3) Get a reflecting level adapted to fit the slot of telescope tube in the pocket sextant; make the reflection of object coincide with reflection of centre of bubble. Then angle read off on vernier = angle of depression.
By these two last methods one can turn the pocket sextant into a good clinometer. I have used these methods (except the last) for the last thirteen years, for finding ranges and sketching, and think they may prove of use to those who possess the "Handbook for Field Service."

82. Electro-Ballistic Experiments.—Captain W. H. Noble submits for record the following table, giving the calculated remaining velocity and energy, at various distances, of projectiles fired from the service M.L.R. guns with battering charges of R.L.G. powder. A similar table, with battering charges of pebble powder, is in course of preparation :—

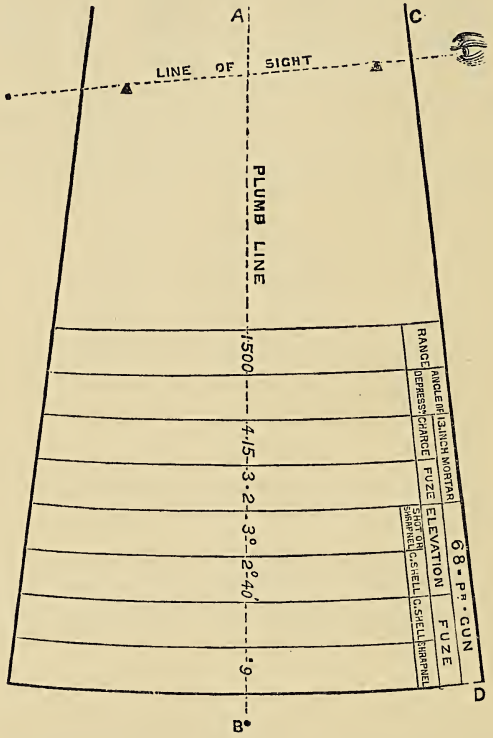
Range.	12-inch M.L.R. of 25 tons. charge 67 lbs., pro. 600 lbs.			10-inch M.L.R. of 18 tons. charge 60 lbs., pro. 400 lbs.			9-inch M.L.R. of 12 tons. charge 43 lbs., pro. 250 lbs.			8-inch M.L.R. of 9 tons. charge 30 lbs., pro. 180 lbs.			7-inch M.L.R. of 6½ tons. charge 22 lbs., p.o. 115 lbs.		
	v.	Total energy.	Energy per inch of shot's circumference.	v.	Total energy.	Energy per inch of shot's circumference.	v.	Total energy.	Energy per inch of shot's circumference.	v.	Total energy.	Energy per inch of shot's circumference.	v.	Total energy.	Energy per inch of shot's circumference.
yds.	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons
0	1180	5793	154·7	1298	4673	150·0	1336	3094	110·4	1363	2319	93·2	1430	1631	75·0
200	1157	5569	148·7	1272	4488	144·0	1300	2930	104·6	1320	2175	87·4	1375	1508	69·4
400	1137	5379	143·6	1246	4306	138·2	1266	2778	99·2	1279	2042	82·1	1325	1400	64·4
600	1118	5200	138·9	1220	4128	132·5	1232	2631	93·9	1243	1928	77·5	1278	1302	59·9
800	1101	5043	134·7	1196	3967	127·3	1200	2496	89·1	1208	1821	73·2	1235	1216	55·9
1000	1085	4898	130·8	1173	3816	122·5	1170	2373	84·7	1176	1726	69·4	1195	1139	52·4
1200	1069	4754	127·0	1151	3675	117·9	1143	2265	80·8	1146	1639	65·9	1156	1066	49·0
1400	1055	4631	123·7	1131	3548	113·9	1119	2171	77·5	1118	1560	62·7	1121	1002	46·1
1600	1041	4509	120·4	1112	3430	110·1	1096	2082	74·3	1093	1491	59·9	1090	947	43·6
1800	1028	4397	117·4	1094	3320	106·5	1074	2000	71·4	1071	1432	57·5	1062	899	41·4
2000	1016	4295	114·7	1076	3211	103·0	1053	1922	68·6	1051	1379	55·4	1037	858	39·4
2200	1004	4194	112·0	1061	3122	100·2	1034	1853	66·1	1031	1327	53·3	1014	820	37·7
2400	993	4102	109·6	1047	3041	97·6	1017	1793	64·0	1012	1278	51·4	994	788	36·2
2600	984	4029	107·6	1033	2960	95·0	1002	1741	62·1	995	1236	49·7	977	761	35·0
2800	976	3963	105·8	1021	2891	92·8	988	1692	60·4	979	1196	48·1	963	740	34·0
3000	968	3899	104·1	1009	2824	90·6	976	1651	58·9	963	1158	46·5	949	718	33·0

83. On the best means of ensuring Accurate Practice at Shipping from elevated Coast Batteries. Communicated by Captain J. R. Oliver, R.A.

In "Short Notes," p. 122, Lieut. G. Mackinlay, R.A., describes an ingenious contrivance for finding the distances of ships at sea from elevated coast batteries. When the battery is at only a moderate height above the sea it is necessary not only to measure the angle of depression with great accuracy, but to allow for the rise and fall of the tide; and in this case the scale which Lieut. Mackinlay proposes to use in conjunction with Bell's hydroscope would undoubtedly be most useful. But if the elevation of the battery is considerable (as is the case with several of those at Gibraltar and St. Helena), the rough instrument of which an account was given in "Proceedings, R.A. Institution," Vol. VI. p. 7, is sufficiently accurate for all practical purposes, and has the additional advantages of being extremely

simple and of requiring no adjustment whatever. All that is necessary is to turn the sights on the water-line of a ship and read off on the face of the clinometer the required information as to elevation, length of fuze, &c. It is not even necessary for the gunners to trouble themselves about the range.

The best plan to adopt is as follows :—The instrument having been constructed and set up, and the sights fixed on its face (which has been left blank), draw on the latter a sector of a circle, having its centre at the point of suspension of the plumb line. Within this sector construct a table according to the different natures of ordnance in the battery. In the accompanying figure the table is supposed to be for a battery of 68-pr. guns and 13-inch mortars. The line *CD* of the sector is, in general, placed at right angles to the line of sight.



The headings having been filled in, as shewn in the figure, the calculated ranges corresponding to different angles of depression may be inserted, and the elevations, lengths of fuze, &c., &c., for each taken from the ordinary range tables. But a better way is to obtain all the information wanted by actual practice at floating targets. Thus, suppose a target to have been fixed at about 1500 yds. from the battery, the sights of the clinometer turned on it, and the plumb line to hang in the position *AB*; a very few trial shots with each description of ordnance will be sufficient to enable us to fill in on the line *AB* all the elevations and lengths of fuze wanted. The target may then be moved a little further out or in, and the same process repeated, when we shall obtain the correct set of figures for

another position of the plumb line. In this manner the table may be completely filled up for the whole extent of the range of the ordnance in position.

The advantages gained by enabling any gunner who can read to ascertain by simple inspection exactly how to lay his gun at any particular moment are self-evident; and even in the case of the plumb-line happening to fall between two rows of figures it will not require much intelligence to enable him to obtain a correct result, by striking, as it were, a mean between the two adjacent figures.

84. Piling of Shot and Shell. Elongated Projectiles. Communicated by Captain R. O'Hara, R.A.

Formula recommended :—

Let B = number in breadth of pile;

L = number in length "

$$S = \frac{BL}{2}(B + 1).$$

85. Picric Powder.—The Chemist, War Department, 18. 7. 70, after prosecuting experiments with a view to providing an explosive agent as a material for charging shells, in continuation of those carried on by the late Ordnance Select Committee (see Minute 26,361, Extracts from Reports and Proceedings of Ordnance Select Committee, Vol. VI. p. 488), has succeeded in producing an explosive agent (or mixture) which, though not so violent in its action as gun-cotton, nitro-glycerine, or picrate of potash powders, is a much more powerful explosive agent than gunpowder, and has other properties which appear to render it peculiarly adapted for employment in shells.

This explosive agent, to which he gives the name of "picric" powder, is readily and expeditiously prepared, and it may be pressed and granulated without difficulty. It is particularly remarkable for its *safety*, as compared with all other explosive agents; it is, in fact, somewhat *less* sensitive to ignition by percussion than gunpowder.

He suggests that the Committee on Explosives be instructed to report upon the merits of this explosive agent, and its fitness for service purposes.

Director of Artillery, 19. 7. 70, forwards to President of Committee on Explosives for early consideration and report.

President, 22. 7. 70, thinks the "picric" powder well worthy of further experiments, and will demand some of this material (100 lbs.) for preliminary trial in twenty 40-pr. shells issued on Demand No. 5913, for a similar purpose, to ascertain, in the first instance, whether the loaded shell will sustain the explosion of the firing charge.

86. Time and Percussion Fuzes for Field Artillery.—The following is an abstract of the Report of the Special Committee lately appointed:—

They have drawn up a short historical record of the fuzes of both classes, namely, time and percussion, from the first introduction of breech-loading guns into the service up to the present date.

This record embraces every modification of the two descriptions of fuzes, which from time to time has been proposed and tried, as well as a summary of the defects which have successively appeared, and the changes which have been made with a view to remedy them.

In order to ascertain the present condition of the fuzes in the service, the Committee selected a certain number of each description as representing those now in store, and were furnished with 25 field service percussion fuzes from those at present carried in the boxes of each battery of field artillery.

The time fuzes, drawn exclusively from store, were subjected to the ordinary Laboratory tests.

The results of these experiments indicated that the detonators of the time fuzes generally were not satisfactory. Under these circumstances, and looking to the fact that the withdrawal of this description of fuze has been repeatedly recommended, the Committee did not consider it necessary to continue this test any further.

The field service percussion fuzes were subjected to the following tests:—

(*a.*) The detonators were removed from 25 of each lot of fuzes, and proved by allowing a weight of 100 grains, with needle point, to fall upon them through a distance of 10 ins., the test being once repeated if necessary.

(*b.*) A certain proportion of each variety were fired with service charges from 12-pr. and 9-pr. breech-loading rifled guns, in both segment and common shells, and the results show that the only fuze of the several varieties included under the description "field service percussion" at all trustworthy, is that known as the Armstrong *C* percussion with safety pin.

Of 200 selected from those in store, some of which had been returned from the Mauritius and other foreign stations, there were of Armstrong *C* percussion with safety pin, 91 good and 9 blind, when fired in 12-pr. and 9-pr. breech-loading rifled guns; 10 screwed *C* percussion were all good, and of the remaining 90 fuzes, Freeth and Dyer patterns, there were 71 good, 4 premature, and 15 blind.

Of the fuzes now carried by the field artillery, four were taken from those returned by each battery for the firing test, making a total of 104.

Of these, 9 were Armstrong *C* percussion fuzes, and all were good.

Of the remaining 95 (Dyer and Freeth patterns) 72 were good, 3 premature, and 20 blind.

These experiments confirm those made at Dartmoor and elsewhere, and demonstrate in the clearest manner that the varieties of field service percussion fuze known as Freeth and Dyer are not to be depended on, a large percentage being either premature or blind.

On a careful review of the whole question, the Committee made the following recommendations :—

1. The immediate withdrawal of the *E* time fuze for breech-loading guns from both land and sea service, using segment shell with percussion fuzes for bursting on graze, and shrapnel shell with wood time fuzes when the nature of the operations requires the use of a time shell.

2. The immediate withdrawal of all field service percussion fuzes of Freeth and Dyer patterns from land and sea service; the cases being made available for conversion into *C* percussion fuzes with new safety pin if required.

3. The withdrawal by degrees of all Armstrong *C* percussion fuzes with and without safety pins, for alteration of safety pin and re-priming.

4. The issue from store, in lieu of the above, of Armstrong *C* percussion fuzes with a safety pin of improved pattern, as lately devised in Royal Laboratory.

These fuzes to be previously re-primed with cap arrangement.

5. This will provide for immediate necessities, but the Committee have in view a fuze which they think will prove to be superior to any of the above patterns, and they recommend that experiments be instituted with the new safety percussion fuze proposed by Sir W. Armstrong and Co. as a fuze to carry in loaded shell. 700 of these fuzes to be ordered at once, and submitted to the following tests :—

100 to be fired in segment shell from 12-pr. breech-loading gun, to burst on graze.

100 to be fired in common shell from 9-pr. muzzle-loading gun, to burst on graze.

200 to be distributed to batteries and travelled in the limber boxes, 100 fixed in unfilled common and segment shells, and 100 carried in the usual boxes.

The main object of this trial is to ascertain whether there is any liability to work loose, either in the fuze or in the projectile, when travelling.

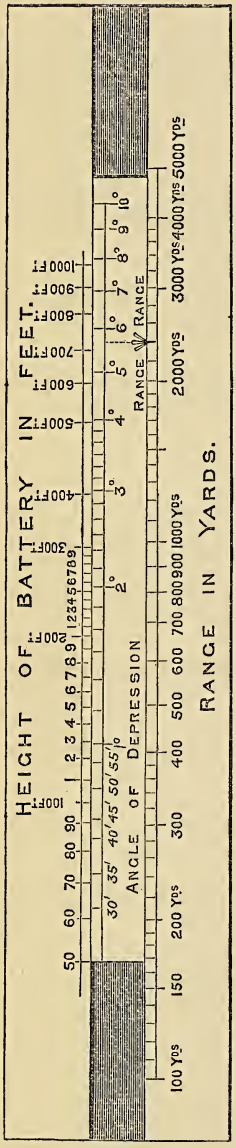
100 to be submitted to the usual Laboratory tests, including jolting.

200 to be sent to H.M.S. "Excellent."

The above fuzes to be primed with cap composition.

The above recommendations have been approved, with the exception of the withdrawal of the *E* time fuze from the naval service. The Admiralty wish to keep this fuze so long as B.L. guns are supplied for boat service.

87. Directions for the use of Captain Tracey's Range Scale. Communicated by the inventor, Captain H. A. Tracey, R.A.



1. Obtain the angle of depression to the target. The gun itself, with a spirit-level or plummet, is a good instrument to do it with, and always ready to hand.

2. The height of the battery above the sea being known, make the angle of depression just obtained, as read on the sliding scale, correspond therewith, when the ⏚ will point to the range.

This scale is an adaptation of "Gunter's Logarithmic Lines." The lower course is simply a line of numbers (marked *N* on the Gunter lines on a sector), and the upper is the same, only arranged to read off feet instead of yards.

The slider is a logarithmic line of tangents, and enables one to perform mechanically the processes necessary for the solution of right-angled triangles in which one side and the opposite angle are known.

This mechanical application of logarithms has the following advantages:—

1. A special scale is not wanted for every height. It is of universal application.

2. Accurate correction can be made for rise or fall of tide.

3. The smaller the angle of depression and the lower the height of the battery, the clearer, more distinct, and therefore more accurate becomes the scale.

In the scale as made by Elliott Brothers (not quite twice the size of the cut), every minute of angle up to one degree is shown without crowding; and up to 100, every other foot is marked. This allows corrections to be made to within one minute of angle, and our guns do not read to less.

At the suggestion of the Committee of the R.A. Institution, this scale has been submitted to the Director of Artillery. Its manufacture (experimentally) has since been authorised, and it is now before the "Engineer Committee."

88. Method adopted for hoisting in the 9-in. M.L.R. Gun at Fort Picklecombe, Plymouth. Communicated by Lieut. W. L. Hutchinson, R.A.

1. The spar is a 60 ft. spar, mean diameter 16 ins. This spar is considerably weather-worn, and has frequently been used in erecting sheers. It is shown in the plan as only 50 ft. in length, on account of the size of the paper.

2. The right guy (chain) is secured to the spar by three half-hitches, three or four links at the end of the chain being allowed to hang down as a precautionary measure, so that a gyn tackle could be hooked in and made fast to a strap at the muzzle of the gun on its being hauled into the casemate (if found necessary.)

N.B.—Six guns have already been hoisted into the work without employing this preventor tackle.

A thin rope is passed three times round the spar, immediately under the chain, so as to jam it, should it slip down. The other extremity of the chain is secured to two Lewes's, fixed in the stonework on the right flank of the fort.

3. The plan of securing the back guy is distinctly shown in the drawing. It is laid on skidding on the top of the work, to prevent damage being done to the asphalte, with which the roof is covered.

4. As soon as the gun is raised a few feet off the ground, sand bags are placed underneath it, and also on the stonework in front of the lower tier of casemates, to receive the gun in case of anything giving way.

5. Before being hauled into the casemates, the guns are received on a wooden staging erected by the Royal Engineers for this purpose, the top being level with the flooring on upper tier of casemates.

6. The winch in the lower casemate is secured to one of the ring bolts let into the flooring, and the running end of the fall, after passing round the barrel, is drawn through a leading block, as there is not sufficient room for the men to hold on directly in rear in consequence of the partition wall.

7. The winch in the upper casemate is secured to skidding, laid across the doorway leading into the casemate from the verandah in rear.

8. The gyn tackle secured to the sling and one of the bolts in the roof, is used as a preventor tackle when the main fall is being eased off. (*Vide* Sectional Elevation).

N.B.—The actual time it takes to raise a gun from the foot of the derrick to the upper tier of casemates (exclusive of stoppering the fall, &c.) is a little over an hour.

89. Captain J. P. Nolan's Range-finder. Communicated by the inventor.

In No. 87 "Short Notes on Professional Subjects," published with No. 3, Vol. VII. of the "Proceedings," is a diagram for finding ranges, by Captain Tracey, R.A. In the "Mechanics' Magazine" of February 24 is a drawing of a mechanical calculator for finding ranges, by Lieut. Watkins, R.A. In my possession is a mechanical calculator for determining ranges, the main portion of which closely resembles the other two.

All these mechanical calculators are rulers containing

(1) A line of lays proportional to the bases from which the ranges are measured.

(2) A line of lays proportional to the sines or arcs of small angles.

(3) A line of lays proportional to the ranges to be determined.

In addition, my ruler contains artifices for effecting addition and subtraction.

Except the omission of the artifices for subtraction and addition, the three rulers are almost identical in construction, as they are completely the same in design and principle.

The most curious feature of resemblance is that all three contain a superfluous line of logarithmic divisions; the base line of lays being wholly unnecessary, as the lays of the ranges can be made to serve for the bases as well as for the ranges. This line has been accordingly suppressed by me in my later mechanical calculators.

The resemblance being so very close, I think the dates of the construction of the three range rulers should be compared.

My system was not published until May, 1869; but the original range ruler—that to which I have referred, and which I still possess—was privately shown by me to the Ordnance Select Committee and to some artillery officers in June, 1867.

90. Report of Progress, Committee on Explosive Substances, Jan. 1, 1871.—The proceedings of the Committee on Explosive Substances, in continuation of those noticed in the Memorandum of Progress dated 7th July, 1870,* have embraced the following experiments with gunpowder:—

(*A.*) Conclusion of experiments with the 10-inch gun, fitted with plugs for crusher gauges and the chronoscope apparatus, in its smooth-bored state.

(*B.*) Commencement of experiments with the same gun in a rifled state.

(*C.*) Various experiments with the 8-inch gun, similarly fitted.

(*D.*) Practice from a 12-inch 25-ton rifled gun, fitted with two plugs for crusher gauges.

(*E.*) Practice from rifled service guns of 7 in. calibre and upwards, for the observation of velocities and determination of the range tables applicable to pebble powder.

(*F.*) The use of projectiles, fitted with plugs in their bases, to contain crusher apparatus similar in action to those used in the experimental guns.

(*G.*) The Committee have also made some preliminary trials with a new material, called picric powder, proposed as a bursting charge for shells, by Mr. Abel, Chemist to the War Department. They have tested, by firing for range and accuracy, some gun-cotton cartridges for small-arms, prepared by Mr. Punshon; and they have likewise tried a description of powder, submitted by Mr. Hahn, as a substitute for gunpowder in all its applications.

(*A.*) 10-*inch Experimental Gun, No.* 375, *Smooth-bore.*

117 experimental rounds were fired from this gun before rifling the bore; 97 of these were noticed in the Memorandum of 7th July, 1870, the remaining 20 consisted of L.G., pebble, and pellet powders; viz.:—

6	rounds of	L.G.	charge	60 lbs.
6	"	Pebble	"	70 lbs.
6	"	Pellet	"	64 lbs.
2	"	Spherical pellet	"	64 lbs. and 70 lbs.

The L.G. powder was fired with the view of comparing its effects with those of R.L.G. Similar trials were made with the 8-inch experimental gun, and the detailed results are given at p. 146. In the 10-inch gun the mean velocities with L.G. were about 50 ft. lower than with R.L.G.; the mean maximum pressures were also lower; but the pressures on individual crusher plugs were occasionally as high as would be given by R.L.G.; the pressure on *A* crusher varying from 46 tons to 54½ tons on the square inch.

The pellet powders proved inferior to the pebble; the pressures being fully as high, whilst the velocities were about 50 ft. per second less.

The mean results of the above 20 rounds were as follow:—

* *Vide* "Short Notes on Professional Subjects," p. 128.

	Rounds.	Muzzle velocity.	Pressure by crusher gauge at		
			*A.**	*B.*†	*C.*‡
		f.s.	tons.	tons.	tons.
L.G. ..... charge, 60 lb.; density 1·648...	6	1273	49	28	29
Pebble ..... " 70 " " 1·751...	6	1435	22	22	23
Pellet ..... " 64 " " 1·696...	3	1377	21½	21	21
Pellet ..... " 64 " " 1·626...	3	1384	24½	23	24
Spherical pellet " 64 " " 1·677...	1	1352	20	15½	21
Spherical pellet " 70 " " 1·667...	1	1380	22½	26½	28

The Committee take this opportunity of drawing attention to the very high pressures indicated at the point *A* by quick-burning powders, such as L.G. and R.L.G.

These indications of violent action are probably due in a great measure to the conical form of the chamber. There are on record numerous instances in which the metal of the bore or tube has been gradually eaten into at a point corresponding to the position of the *A* crusher, namely, the centre of the bottom of the bore.

The Committee have selected the following examples of this peculiar action which has been attributed to the particular form of chamber in each case:—

(1) In the trial for endurance in 1867 of the 9-inch M.L.R. guns of 12 tons, a hole about 3 ins. deep was eaten into the end of the steel tube of gun No. 330 after 500 rounds. This result was attributed by the Superintendent Royal Gun Factories to the conical nature of the chamber. (Proceedings O.S.C., 1867, pp. 829–30–31–32.)

(2) A large cavity over 2 ins. in depth was developed in the bottom of the wrought-iron bore of the experimental 9-inch gun No. 331, during the above trial of endurance, after 500 rounds. (Proceedings O.S.C., 1867, pp. 1068–69.)

(3) In testing the endurance of a 6·5-inch smooth-bore gun (Experimental No. 100), with inner barrel of solid forged wrought-iron, a large cavity was observed at the bottom of the bore, after 60 rounds. After 100 rounds this hole measured 2″ × 1·5″ and 2·75″ in depth, with fissures extending from its edge. (Proceedings O.S.C., 1862, pp. 540–41.)

(4) During the trial in 1864 of the 7-inch M.L.R. wrought-iron guns rifled on different systems, three of the guns were severely injured by their steel tubes being eaten into at the bottom of the bore. (Proceedings O.S.C., 1864, p. 627; 1865, p. 343).

(5) During the trial in 1865 of the 7-inch M.L.R. gun No. 217, a hole of 2½ ins. in depth was eaten into the end of the solid steel tube, thus rendering the gun unserviceable. (Proceedings O.S.C., 1865, p. 636.)

(6) Many cast-iron mortars have been rendered unserviceable by holes eaten in this manner into the bottom of the chamber; and numerous instances exist in which mortars have split and burst from this cause.

The 10-inch Experimental Gun No. 375, is chambered in the same manner as the service M.L.R. 10-inch guns.

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* Axis of bore. † Centre of Charge. ‡ Front of Charge.

The 8-inch Experimental Gun No. 288, is unchambered, and the pressures indicated at *A* in this gun are not relatively so high as those indicated at the same point in the 10-inch gun.

On the whole, the Committee are disposed to look upon the pressure at *A* as intensely local, and as not representing the actual or average pressure over the entire bottom of the bore.

They think, however, that the pressures at *B* and *C* give a very fair measure of the pressure in the powder-chamber.

When firing battering charges of pebble powder in M.L.R. guns up to and including the 12-inch of 25 tons, this intense local action at *A* disappears, and the pressure over the whole of the powder-chamber seems to be uniform.

The experiments carried out with the 10-inch gun before being rifled may be summarised thus, including 6 rounds (4 with pebble and 2 with R.L.G.) fired for velocity before the fittings of the gun were completed :—

Powder.	Charge.	Number of rounds.	Amount of powder.
	lbs.		lbs.
R.L.G.	60	30	1800
L.G.	60	6	360
Pebble	70	43	3190
	60	2	
Pellet	70	6	1829
	65	1	
	64	21	
Prismatic	70	1	870
	68	1	
	61	12	
Total	...	123	8049

(*B.*) 10-*inch Experimental Gun, No.* 375, *Rifled.*

In rifling this gun, the number of grooves had to be restricted to two, in order to avoid interference with the numerous plugs fitted into it. The rotary motion of the shot on its own axis has consequently to be imparted by only two driving surfaces instead of seven, and the result is that the edges of the grooves have a tendency to become slightly burred and set up. This sometimes interferes with the loading, as the windage is very small; but no other inconvenience or difficulty has been experienced since the rifling was introduced.

29 rounds have been fired from the gun in its rifled state—viz., 17 of R.L.G., charge 60 lbs., and 12 of pebble, charge 70 lbs. The mean velocities and pressures were as follow :—

		Muzzle velocity.	Pressure by crusher gauge at		
			A.	*B.*	*C.*
		f.s.	tons.	tons.	tons.
R.L.G., 60 lbs.	Curtis & Harvey ..... density 1·675	1325	53½	32	25
	Waltham Abbey..... " 1·724	1312	37½	30½	26½
	Ditto, re-worked from Pigou and Wilks L.G. ..... " 1·743	1337	43½	29½	27½
Pebble, 70 lbs., Waltham Abbey	Date, 16. 5. 70	1423	21¼	20½	20½
	„ 15. 10. 70	1383	20¼	20	20

A comparison of the velocities and pressures before and after rifling is contained in the following table, and shows no difference greater than what is liable to exist between different series of trials when the conditions are intended to be similar in all respects:—

			Muzzle velocity.	Pressure by crusher gauge at		
				A.	*B.*	*C.*
			f.s.	tons.	tons.	tons.
R.L.G., charge 60 lbs.	Curtis & Harvey, density 1·675	Gun, smooth...	1322	53	27½	26
		" rifled ...	1325	53½	32	25
	Waltham Abbey, " 1·724	" smooth...	1330	48	31	25
		" rifled ...	1313	37½	30½	26½
Pebble...Date Charge 70 lbs.	16. 5. 70 ... 29. 7. 70 15. 10. 70 — Waltham Abbey...	" smooth...	1443	21	21	20
		" rifled ...	1423	21¼	20½	20½
		" smooth...	1435	22	22	23
		" rifled ...	1383	20	20	20

The general results exhibit a slight diminution of velocity, and likewise a slight diminution of pressure consequent on the rifling. These results are insufficient to form a basis for any general conclusion; they however appear to indicate that there is no important difference in either velocity or pressure between the gun in its rifled and in its smooth-bore state.

(*C.*) 8-*inch Experimental Gun, No.* 288, *Smooth-bore.*

59 rounds have been fired from the 8-inch experimental gun since the Preliminary Report of 5th February 1870 was drawn up; 22 of these were battering charges for proof of various kinds of pebble powder; 20 rounds formed a portion of the experiments with projectiles of increasing weights, noticed in the Memorandum of 7th July, 1870, and 15 were fired with a 69 lb. round shot and various kinds of powder, principally to ascertain the pressure exerted in 68-pr. smooth-bored guns with service charges of L.G. and R.L.G. powders. Two rounds consisted of blank charges of 30 lbs. R.L.G.; with these the pressures indicated at *A*, *B*, and *C* were 15¼, 9¾, and 9 tons per square inch respectively. The pressure at *A* was about the same as had been given at the same point in firing a cylinder of 170 lbs. weight with 35 lbs. of pebble powder.

The series of experiments with projectiles of increasing weights is not yet completed; the trials with a 69 lb. round shot gave the following average results:—

			Number of rounds.	Muzzle velocity.	Pressure by crusher gauge at		
					A.	*B.*	*C.*
				f.s.	tons.	tons.	tons.
R.L.G....16 lbs.	Curtis & Harvey.....density, 1·675		3	1705	19	12	24
	Waltham Abbey..... " 1·732		3	1658	16⅔	11	16
L.G.....16 lbs.	Curtis & Harvey..... " 1·648		3	1686	15	9⅔	17⅔
	Pigou & Wilks ..... " 1·637		3	1679	12	11	17⅔
Pebble	16 lbs.	Waltham Abbey, 23. 5. 70. " 1·78	1	1410	4½	3¼	2
	18 lbs.	" "	1	1478	2½	2½	3
	20 lbs.	" "	1	1547	3	5	2½

The 16 lb. cartridge being only 12 ins. long, the *C* crusher was a little behind the centre of the shot, but nearly in the position of least windage. The pressure on this crusher was greater than that on the axial crusher, *A*, in nine out of the twelve rounds with R.L.G. and L.G. powders, and equal to it in one of the other three. The two L.G. powders gave, on the whole, a rather less pressure than the R.L.G.

In making experiments to determine the comparative effects of L.G. and R.L.G powders, it is difficult to obtain exact indications of the difference due solely to the size of grain (by which principally R.L.G. is intended to be distinguishable from L.G.), on account of their generally differing also in the very important quality of density, and occasionally in other points—such as the nature of charcoal, and the tendency to a flaky form of grain. It is however important to ascertain whether R.L.G. is liable under any conditions to be more destructive than L.G., or *vice versâ*, as it affects the practicability of making these two powders interchangeable for service or battering charges.

Up to the end of December, 1870, the Committee had fired 44 rounds of R.L.G. and L.G. suitable for the purposes of this comparison—viz., 24 with the 10-inch gun and 400 lb. shot; 8 with the 8-inch gun and 180 lb. shot; and 12 with the same gun and a 69 lb. shot; the average results are as follow :—

10-*inch Gun, Smooth-bore.*

	Number of rounds.	Muzzle velocity.	Pressure by crusher gauge at		
			A.	*B.*	*C.*
400 lb. Shot.		f.s.	tons.	tons.	tons.
R.L.G. density, 1·742; 60 lbs....	6	1327	51	32	26
R.L.G. " 1·733; " ...	6	1330	48	31	25
R.L.G. " 1·675; " ...	6	1322	53	27½	26
L.G. ..... " 1·648; " ...	6	1273	49	28	31

8-*inch Gun, Smooth-bore.*

	Number of rounds.	Muzzle velocity.	Pressure by crusher gauge at		
			A.	*B.*	*C.*
180 lb. Shot.		f.s.	tons.	tons.	tons.
R.L.G....density, 1·675; 30 lbs.	4	1374	29½	24¾	21
L.G..... " 1·648; "	4	1319	28	22½	20½
69 lb. Shot.					
R.L.G....density, 1·675; 16 lbs.	3	1705	19	12	24
" " 1·732; "	3	1658	16⅔	11	16
L.G..... " 1·648; "	3	1686	15	9⅔	17⅔
" " 1·637; "	3	1679	12	11	17⅔

In the above tables there is only one instance in which a material difference is shown in the pressures—viz., the first series of R.L.G. with 69 lb. shot. This powder, which was manufactured by Messrs. Curtis and Harvey, is decidedly of a quick action, and has been employed as a representative of such powders in various series of experiments. The velocities with the L.G. have, however, been lower in every series except the one in which R.L.G. powder of high density, 1·732, was used with a 69 lb. shot. The normal muzzle velocity in a 68-pr. cast-iron gun, with 16 lb. L.G. and service shot (which leaves a larger windage than existed in these experiments, and is rather lighter), is only 1579 ft. per second. It would consequently appear that there need be no hesitation in interchanging L.G. with R.L.G. in wrought-iron guns on the ground of danger to the gun, but the substitution would be attended with a falling off in muzzle velocity, power, and shooting qualities.

In experimenting with the 8-inch gun, the copper cylinders by which the pressure is measured at the front of the cartridge have been placed occasionally in the same position as the Rodman knives which were employed for that purpose during the early stages of the Committee's experiments; that is to say, they were put at the outside surface of the gun, instead of being situated close to the bore. In all the five cases when this was done an enormous increase of compression resulted, as will be clearly seen from the following table, the differences seem to be greater with R.L.G. and L.G. than with pebble powder. The results fully corroborate the observations on this point at p. 9 of the Preliminary Report, dated 5th Feb. 1870 :—

8-inch Gun.	Muzzle velocity.	Pressure by crusher gauge at			
		A.	*B.*	*C.*	
				Inside.	Outside.
	f.s.	tons.	tons.	tons.	tons.
Pebble	1507	15½	14	16	—
	1508	15	14	—	27
	1502	15½	14½	14½	—
	1512	16	15½	—	26½
R.L.G.	1371	29½	25½	20	—
	1371	30	22½	—	57
L.G.	1317	25	18	—	34½
	1325	36½	27	21½	—
	1314	31½	23	19½	—
	1320	30½	22	—	45½

(*D.*) 12-*inch M.L. Rifled Gun of* 25 *tons.*

One of these guns (No. 372) has been fitted with two plugs for crusher gauges in positions corresponding to *A* and *B* in the 8-inch and 10-inch guns—viz., *A* through the cascable, in continuation of the axis of the bore, and *B* through the side of the powder-chamber at the centre of the charge. Fifteen rounds have been

fired for observation of pressure—ten with 85 lbs. pebble and five with 67 lbs. R.L.G. powder. The mean velocities and pressures were as follow, the projectile weighing 600 lbs. :—

	No. of rounds.	Muzzle velocity.	Pressure by crusher gauge at		
			A.	*B.*	Base of shot.
		f.s.	tons.	tons.	tons.
R.L.G., 67 lbs.	5	1168	21·9	17·8	19·0
Pebble, 85 lbs.	10	1297	18·0	16·8	15·0

It will be observed that the pressure indicated by the battering charge of R.L.G. in the above gun is considerably lower than that given by the battering charge in the other heavy M.L.R. guns; this is probably owing to the relative smallness of the charge as compared with the weight of the shot and the calibre of the gun.

(*E.*) *Practice from Service Rifled Guns.*

The following table contains an abstract of the velocities obtained with various charges of pebble and R.L.G. powder from service guns at Shoeburyness. The muzzle velocity of the 10-inch service gun is only 1364 ft. as compared with 1383 ft. and 1423 ft. with the two kinds of pebble powder fired from the experimental rifled gun. This difference may be accounted for by the latter having only ·02 in. windage instead of ·08 in., and only two grooves instead of seven, in addition to any other variations in the state of the bore. In the practice with the 7-inch gun there was found to be a difference of 30 ft. per second between the velocities given by an old gun much scored in the bore and a new one, when pebble powder was used, and 70 ft. when R.L.G. powder was used:—

Guns.	Pebble powder.		R.L.G. powder.		Normal muzzle velocity.
	Charge.	Mean muzzle velocity.	Charge.	Mean muzzle velocity.	
	lbs.	f.s.	lbs.	f.s.	f.s.
12-inch M.L.R. of 25 tons; 600 lbs. projectile ...	85	1300	67	1161	1180
	80	1255	67	1168	
	75	1235	—	—	
10-inch M.L.R. of 18 tons; 400 lbs. "	70	1364	60	1280*	1298
9-inch M.L.R. of 12 tons; 250 lbs. " ...	50	1420	43	1338	1336
	48	1386	43	1316	
	46	1362	43	1381*	
8-inch M.L.R. of 9 tons; 180 lbs. " ...	35	1413	30	1330*	1363
	35	1384	30	1314	
	30	1364	—	—	
7-inch M.L.R., 115 lbs. projectile, of 7 tons; length of bore, 10 ft. 6 ins....	25	1465	—	—	—
of 6½ " † " 9 ft. 3 ins.	28	1447	22	1315	1430
	30	1493	22	1366*	
" " " (new)	30	1525	22	1435*	

* Re-worked from Pigou and Wilks L.G.

† Much scored; previously fired 1729 rounds.

(*F.*) *Projectiles fitted with Crusher Gauges.*

The Committee have commenced experiments with projectiles fitted, in the centre of their bases, with crusher gauges, in order to ascertain whether the compression of a copper cylinder thus placed would indicate with sufficient exactness the pressure in the powder-chamber, as shown by the crusher gauges in the gun, so as to be taken as a criterion of the pressures exerted by various charges. If this mode of measuring pressure should prove feasible, it would furnish a convenient test applicable to any large gun without further fittings or arrangements. The following tables show the results hitherto obtained with crushers in the projectiles:—

	Muzzle velocity.	Pressure by crusher gauge at				
		A.	*B.*	*C.*	Base of projectile.	
	f.s.	tons.	tons.	tons.	tons.	
10-inch gun, 64 lb. pellet...	1392	21·7	21·4	24·6	22·0	The position of *C* plug in the gun corresponds with that of the base of the shot.
	1380	29·0	21·7	22·8	22·0	
	1380	21·8	19·3	23·4	18·5	
12-inch gun, 85 lb. pebble...	1287	19·1	18·2	—	15·0	
12-inch gun, 67 lb. R.L.G.	1163	23·7	17·9	—	21·9	
	1152	—	15·8	—	16·0	

The next table shows the results in 7-inch, 9-inch, and 12-inch guns, which were not fitted with crusher plugs; the projectiles however were provided with them in the base.

	Pebble powder.			R.L.G. powder.	
	Muzzle velocity.	Projectile crusher.		Muzzle velocity.	Projectile crusher.
	f.s.	tons.		f.s.	tons.
12-inch gun	1235	16·6	12-inch gun	1161	21·0
9-inch gun	1362	11·6	9-inch gun	1317	17·2
		14·8			16·0
	1420	11·2		1312	14·8
		10·3		1381	18·7
		10·9			19·6
					21·1
				1338	20·5
7-inch gun	1525	10·6	7-inch gun	1435	15·7
		10·4			17·0

(*G.*) *Miscellaneous Experiments.*

Shells filled with picric powder have been fired from the 40-pr. B.L. and 7-inch M.L. rifled gun, to ascertain whether the material is so sensitive as to explode by the shock of the discharge. No such explosion having occurred in twenty rounds, further experiments will be made with the view of testing its destructive effect under the conditions of ordinary use.

Mr. Punshon's gun-cotton, and Mr. Hahn's powder, were fired from a Martini-Henry rifle, and the results compared with those of service gunpowder cartridges

fired at the same time and under similar conditions. Both proved inferior in range and regularity, the mean results being as follow :—

Punshon Gun-cotton Cartridges fired in comparison with Service Gunpowder Cartridges at target, 500 yds. range.

	Mean radial deviation.	
	Gun-cotton.	Gunpowder.
	ft.	ft.
1st series, 9 cartridges	4·17	·44
2nd " 10 "	2·70	·47

Mr. Hahn's Powder, in comparison with Service Powder.

	Hahn's powder.		Service powder.		
	Observed velocity.*	Mean difference of velocity.		Observed velocity.*	Mean difference of velocity.
	f.s.	ft.		f.s.	ft.
For velocity { charge 45 grains ...	1060	17	Service cartridge	1285	4
" 55 " ...	1082	13	" "	1267	3
" 60 " ...	1072	27			
Mean radial deviation on target at 500 yards. Charge 45 grains.....		2·06	" "	—	·78

* At 82 ft. from muzzle.

C. W. YOUNGHUSBAND, Colonel R.A.,

President, Committee on Explosives.

20. 1. 71.

91. Explosive Compound. "Lithofracteur."—Director of Artillery, 28. 2. 71, forwards, for record, a memorandum, dated 21. 2. 71, by Mr. Abel, Chemist to War Department, recording the nature and composition of an explosive agent known as "lithofracteur," used in the Prussian military service for purposes similar to those where compressed gunpowder is employed, an article upon which appeared in the "Times" of 20. 2. 71, written by a military correspondent at Versailles.

The specimen analysed by Mr. Abel in December 1869, consisted of a flattened roll, 4 ins. long, resembling in colour coarse damp clay in its mechanical condition, and enclosed in several folds of thin paper saturated with nitro-glycerine absorbed from the mass thus enclosed. The following is the composition :—

Nitro-glycerine	42	parts.
Nitrate of soda	25	"
Sulphur	4	"
Sand, silicious earth, sawdust, and coarsely powdered coal	29	"
Total	100	

This so-called "lithofracteur" differs from nitro-glycerine preparation termed "dynamite," chiefly in containing a proportion of gunpowder constituents—viz., saltpetre, carbon, and sulphur, mixed up with the other ingredients.

He states that from the analysis of a second sample it would appear that the substance is very crudely mixed, and varies considerably in composition, and that there is no reason whatever to consider this preparation an improvement upon dynamite. It would certainly not be more violent in action; and the circumstance that in any application of it the hands of the operators must become soiled with the poisonous nitro-glycerine, constitutes a very serious objection.

92. Hydraulic Lifting Jack.*—It has been noticed that artillerymen working this jack, neglect to loosen the screw plug in the head. If this is not done, air cannot enter when the jack is required to be lowered, and it remains in a raised position. When this occurs it is supposed that the jack is out of order.

The screw plug should be replaced when the jack is to be transported.

It may be well to use caution in lowering great weights by hydraulic jacks. For instance, if the breach of a gun is supported on two jacks at the end of a beam, and one is lowered quickly, before the other, the gun may roll over; or if the breech is on kidding, and the muzzle is lowered rapidly, and beyond 4° depression, the gun is apt to upset the skidding and slip to the front. These accidents are not likely to occur with screw jacks, considerable time being required to lower a weight.

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* *Vide* Carriage Department lithograph, No. 79.

93. Table giving the calculated remaining velocity and energy, at various distances, of projectiles fired from the service M.L.R. guns with battering charges of P. powder. (*Submitted to Department of Director of Artillery by Captain W. H. Noble, R.A.*, 1. 4. 71. *A table at par.* 82, *page* 135 "*Short Notes,*" *affords corresponding results with R.L.G. powder.*)

Range.	12-inch M.L.R. of 25 tons. charge 85 lbs., pro. 600 lbs.			11-inch M.L.R. of 25 tons. charge 85 lbs., pro. 535 lbs.			10-inch M.L.R. of 18 tons. charge 70 lbs., pro. 400 lbs.			9-inch M.L.R. of 12 tons. charge 50 lbs., pro. 250 lbs.			8-inch M.L.R. of 9 tons. charge 35 lbs., pro. 180 lbs.			7-inch M.L.R. of 6½ tons. charge 30 lbs., pro. 115 lbs.		
	v.	Total energy.	Energy per inch of shot's circumference.	*v.*	Total energy.	Energy per inch of shot's circumference.	*v.*	Total energy.	Energy per inch of shot's circumference.	*v.*	Total energy.	Energy per inch of shot's circumference.	*v.*	Total energy.	Energy per inch of shot's circumference.	*v.*	Total energy.	Energy per inch of shot's circumference.
yds.	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons	ft.	ft.tons	ft.tons
0	1300	7030	188	1315	6415	187	1364	5160	165·6	1420	3496	124·7	1413	2492	100·2	1525	1855	85·3
200	1273	6750	181	1289	6165	180	1336	4950	158·9	1379	3297	117·6	1369	2339	94·0	1467	1716	78·9
400	1248	6480	174	1265	5935	173	1308	4745	152·3	1341	3117	111·2	1327	2198	88·3	1409	1583	72·8
600	1224	6230	167	1242	5720	167	1280	4575	146·8	1304	2948	105·2	1286	2064	83·0	1356	1466	67·5
800	1201	6000	161	1220	5520	161	1254	4360	140·0	1270	2796	99·8	1248	1944	78·1	1307	1362	62·7
1000	1179	5780	155	1199	5335	156	1228	4185	134·2	1236	2648	94·5	1213	1837	73·8	1261	1268	58·3
1200	1157	5570	149	1179	5155	150	1204	4020	129·0	1204	2513	89·7	1180	1738	69·9	1217	1181	54·3
1400	1137	5380	144	1159	4985	145	1181	3870	124·1	1174	2389	85·3	1150	1651	66·3	1177	1105	50·8
1600	1118	5200	139	1139	4815	140	1159	3725	120·0	1147	2281	81·4	1122	1571	63 2	1141	1038	47·8
1800	1101	5040	135	1122	4670	136	1138	3590	115·3	1121	2178	77·7	1097	1502	60·4	1108	979	45·0
2000	1085	4890	131	1106	4540	132	1118	3470	111·2	1097	2086	74·4	1074	1440	57·9	1078	927	42·6
2200	1069	4750	127	1090	4410	129	1099	3350	107·5	1075	2003	71·5	1052	1381	55·5	1053	884	40·7
2400	1055	4630	124	1075	4285	125	1082	3245	104·2	1055	1930	68·9	1032	1329	53·4	1030	846	38·9
2600	1041	4510	120	1061	4175	122	1066	3150	101·1	1037	1864	66·5	1014	1283	51·6	1009	812	37·3
2800	1028	4400	117	1048	4075	119	1052	3070	98·5	1020	1804	64·4	996	1238	49·8	990	782	36·0
3000	1016	4300	115	1036	3980	116	1038	2990	95·9	1004	1747	62·4	980	1199	48·2	973	755	34·7
3200	1004	4200	112	1024	3890	113	1025	2915	93·5	990	1699	60·6	965	1162	46·7	958	732	33·7
3400	993	4100	110	1012	3800	111	1013	2845	91·3	978	1658	59·2	952	1131	45·5	945	712	32·8
3600	984	4030	108	1002	3725	109	1002	2785	89·4	966	1618	57·7	940	1103	44·3	934	696	32·0
3800	976	3960	106	994	3665	107	992	2730	87·6	955	1581	56·4	930	1080	43·4	924	681	31·3
4000	968	3900	104	986	3605	105	982	2675	85·8	945	1548	55·2	920	1056	42·5	916	669	30·8

94. Table showing the mean muzzle velocity of projectiles fired from the service rifled guns. (*Submitted to the Department of Director of Artillery by Captain W. H. Noble, R.A.*, 1. 1. 72. *A table at par.* 73, *page* 120 "*Short Notes,*" *gives the velocities obtained with R.L.G. powder only.*)

Nature of Gun.	Calibre.	Length of bore in calibres.	Charge.		Projectile.			Mean muzzle velocity.
			Nature of powder.	Weight.	Nature.	Mean weight.	Mean diameter.	
	ins.			lb. oz.		lbs.	ins.	f.s.
12-inch M.L. of 35 tons	12·0	13 5	P.	110 0	Palliser.	700	11·92	1300
12-inch M.L. of 25 tons	12·0	12·0	P.	85 0	〃	600	11·92	1300
			P.	85 0	Com. shell.	495	11·92	1358
			P.	55 0	〃	495	11·92	1142
			R.L.G	67 0	Palliser.	600	11·92	1180
			R.L.G	67 0	Com. shell.	495	11·92	1271
			R.L.G	50 0	〃	495	11·92	1140
11-inch M.L. of 25 tons	11·0	13·2	P.	85 0	Palliser.	535	10·92	1315
			P.	85 0	Com. shell.	535	10·92	1315
			R.L.G	70 0	Palliser.	535	10·92	1217
			R.L.G	70 0	Com. shell.	535	10·92	1217
10-inch M.L. of 18 tons	10·0	14·5	P.	70 0	Palliser.	400	9·92	1364
			P.	70 0	Com. shell.	400	9·92	1340
			P.	44 0	〃	400	9·92	1125
			R.L.G	60 0	Palliser.	400	9·92	1298
			R.L.G	40 0	Com. shell.	400	9·92	1117
9-inch M.L. of 12 tons	9·0	13·9	P.	50 0	Palliser.	250	8·92	1420
			P.	50 0	Com. shell.	250	8·92	1420
			R.L.G	43 0	Palliser.	250	8·92	1336
			R.L.G	43 0	Com. shell.	250	8·92	1336
			R.L.G	30 0	〃	250	8·92	1192
8-inch M.L. of 9 tons	8·0	14·8	P.	35 0	Palliser.	180	7·92	1413
			P.	35 0	Com. shell.	180	7·92	1413
			R.L.G	30 0	Palliser.	180	7·92	1330
			R.L.G	30 0	Com. shell.	180	7·92	1330
			R.L.G	20 0	〃	180	7·92	1163
7-inch M.L. of 7 tons	7·0	18·0	P.	30 0	Palliser.	115	6·92	1561
			P.	30 0	Com. shell.	115	6·92	1561
			R.L.G	22 0	Palliser.	115	6 92	1458
			R L.G	22 0	Com. shell.	115	6·92	1458
			R.L.G	14 0	〃	115	6·92	1258
7-inch M.L. of 6½ tons	7·0	15·9	P.	30 0	Palliser.	115	6·92	1525
			P.	30 0	Com. shell.	115	6·92	1525
			R.L.G	22 0	Palliser.	115	6·92	1430
			R.L G	22 0	Com. shell.	115	6·92	1430
			R.L.G	14 0	〃	115	6·92	1230
80-pr. M.L. of 101 cwt., converted from 68-pr. S.B. of 95 cwt.	6·3	18·0	L.G.	10 0	〃	80	6·22	1240

(*Continued.*)

Nature of Gun.	Calibre.	Length of bore in calibres.	Charge.		Projectile.			Mean muzzle velocity.
			Nature of powder.	Weight.	Nature.	Mean weight.	Mean diameter.	
	ins.			lb. oz.		lbs.	ins.	f.s.
64-pr. M.L. wrought-iron of 64 cwt.	6·3	15·5	R.L.G	8 0	Com. shell.	64	6·22	1252
			L.G.	8 0	"	64	6·22	1229
64-pr. M.L. of 58 cwt., converted from 32-pr. S.B. of 58 cwt.	6·3	17·2	R.L.G	8 0	"	64	6·22	1245
64-pr. M.L. of 71 cwt., converted from 8-inch S.B. of 65 cwt.	6·3	16·4	R.L.G	8 0	"	64	6·22	1230
40-pr. M.L. of 35 cwt.*	4·75	18·0	R.L.G	8 0	"	40	4·69	1357
			R.L.G	7 0	"	40	4·69	1336
			R.L.G	6 0	"	40	4·69	1305
25-pr. M.L. of 21 cwt.*	4·0	18·0	R.L.G	5 0	"	25	3·94	1355
			R.L.G	4 8	"	25	3·94	1320
			R.L.G	4 0	"	25	3·94	1278
16-pr. M.L. of 12 cwt.	3·6	19·0	R.L.G	3 0†	"	16	3·54	1352
			R.L.G	2 8	"	16	3·54	1273
			R.L.G	2 0	"	16	3·54	1167
9-pr. M.L. of 8 cwt.	3·0	21·3	R.L.G	1 12†	"	9	2·94	1381
			R.L.G	1 8	"	9	2·94	1325
			R.L.G	1 4	"	9	2·94	1203
9-pr. M.L. of 6 cwt.	3·0	17·5	R.L.G	1 12	"	9	2·94	1262
			R.L.G	1 8†	"	9	2·94	1234
7-pr. M.L. of 220 lbs. (bronze).....	3·0	11·3	F.G.	0 12†	"	7·25	2·94	955
			F.G.	0 10	"	7·25	2·94	854
7-pr. M.L. of 150 lbs. (steel)	3·0	8·0	F.G.	0 6	"	7·25	2·94	673
7-inch B.L. of 82 cwt.	7·0	14·2	R.L.G	10 0	"	110	7·09	1013
			R.L.G	11 0	"	90	7·09	1165
64-pr. B.L. of 61 cwt.....	6·4	10·9	R.L.G	9 0	"	64	6·48	1200
40-pr. B.L. of 35 cwt.....	4·75	22·4	R.L.G	5 0	"	41	4·8	1180
20-pr. B.L. of 16 cwt. (land service).	3·75	22·4	R.L.G	2 8	"	21	3·8	1130
20-pr. B.L. of 13 cwt. (sea service).	3·75	14·5	R.L.G	2 8	"	21	3·8	1000
12-pr. B.L. of 8 cwt.	3·0	20·5	R.L.G	1 8	Segt. shell.	11·75	3·07	1150
9-pr. B.L. of 6 cwt.....	3·0	17·7	R.L.G	1 2	"	9·25	3·07	1057
6-pr. B.L. of 3 cwt.....	2·5	21·2	R.L.G	0 12	"	6·6	2·57	1046

* These guns are not yet finally approved of. † Service charge.

95. "Die Kartätschgeschütze." By R. Wille, Prem. Lieut. Berlin, Mittler & Son.

(Contributed by Captain F. C. H. Clarke, R.A.)

This pamphlet is the expression of the general feeling now prevalent in Prussia with regard to the mitrailleuse question.

The opinions formed in Prussia on the use of mitrailleuses in the field have been strengthened by the experiences of the war of 1870–71, and the official determination not to employ them is understood to have been confirmed by the opinions of a large majority of commanding officers of different grades, expressed after practical observation of their effect in the field, and more especially after the break-down of the Bavarian mitrailleuse. These officers are said to have been not only adverse to the introduction of these weapons for field purposes, but to have expressed the feeling that not a single field gun should be withdrawn to make way for the mitrailleuse.

The great objections to its introduction for field service are, that it requires for its efficient employment four horses and at least five men, and that its best range is within rifle range.

After describing the various systems of Kartätschgeschütze, or mitrailleuses, the author gives, as far as is known, the organisation into batteries of the new weapon among the principal European powers. Before taking any steps in this matter, most nations have been naturally waiting to see the *rôle* it would play in the recent war before coming to a decision on the question of organisation; consequently, the information given on this head in the book is incomplete.

With the system of organisation, equipment, &c., in France, the history of the last campaign has made us acquainted.

In England, nothing is at present decided, except that some Gatling guns have been ordered.*

In Austria, in accordance with the Reports of the Military Committee (first half-year, 1871), the War Department has decided to adopt the Montigny system, but has not decided on their distribution, organisation, or equipment.

The Russians have already ordered 15 batteries, which are attached to the 15 infantry divisions in the western part of Russia in Europe, exclusive of the Guards. The system adopted is the Gatling, improved by Gorloff. The battery consists of 10 steel barrels, with the Berdan system of rifling, so as to take the cartridge of that system. The carriage is of iron, and of a new model. 6720 cartridges are carried. The battery is drawn by four horses, the ammunition cart by three horses. Four men are required to serve it.

In Prussia, the captured French mitrailleuses will be utilised for the defence of ditches in caponiers.

The question of their tactical *rôle* is summed up as follows:—

Under any circumstances, we can only expect mitrailleuses to be effective against living objects in the open. So far, they can do no more than small-arms and canister;

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* It is believed that their use will be restricted to flank defence in fortresses, and for boat service.—F. C. H. C.

and much less can their effect be compared with that of a shrapnel shell, which can reach the enemy when under cover, or with that of a common shell, which, by its superior power and great destructive action, is effective against a resisting object, and at greater distances.

Not only are mitrailleuses incapable of competing with field artillery as regards the effects produced, and in a duel with the field gun, except perhaps at close quarters, would certainly come off second best, but they require just as extensive and costly an organisation and equipment as field artillery. Of course, if they are moved on the field by men, their tactical *fiasco* ought to be complete.

In comparison with small-arms, mitrailleuses perform, at the best, as well as the corresponding number of infantry, which in a given time can fire the same number of shots, but with this important difference—that during this time the fighting fire of the infantry has been doing work for the *tactical offensive*. (This has been often proved in the case of the Prussians, by whom accuracy of shooting has been brought to such a pitch of perfection.) Now, the mitrailleuse can play no part *in the offensive*, and even in the *absolute defensive* occasions will more frequently present themselves in war for placing a half-company of infantry in a position favourable for their fire, and in which they are at the same time sheltered, than for placing a battery of six mitrailleuses, whose fire in the same time would not be greater in point of the total number of shots.

On these grounds, we mean to say that the introduction of mitrailleuses, especially for field warfare, is not warranted; and that it would be a fatal error to reduce the field artillery (as the French did last year), or to neglect to increase it, in order to organise a corresponding number of mitrailleuse batteries.

But the more fruitful field for its use will be that which the siege of a fortress offers, and particularly in the fortress for direct defence against storming, as flank and caponier pieces for defence of the main ditch. Where we have to deal with living objects without cover in the open, where the length and breadth of the space which is to be swept lies within very narrow limits, and when as heavy a fire as possible has to be concentrated in a minimum of time and space, in this case all the advantages are decidedly on the side of the mitrailleuse.

By substituting in flanks or caponiers the fire from a few mitrailleuses for that of small-arms and canister, the passage of the main ditch would be rendered almost impracticable for an assailant, and at the same time these weapons offer so small a mark, that the port-holes (which are purposely placed low down so as to bring a grazing fire on the ditch) can hardly be hit, much less destroyed, by the besieger's indirect counter batteries—those most dangerous enemies of flank batteries and caponiers.

We are therefore of opinion that the mitrailleuse only plays a comparatively modest and subordinate part in war, and that its real and successful future will be found rather in sieges.

96. A Proposed Plan for Carrying the Detachments with Field Artillery.

(Communicated by Captain S. Penny, R.A.)

1. To increase the length of the axletree-box to double its present length, to enable two men to be carried back to back, as formerly, on the wagon body.

2. To do away with the iron guard at the back of the axletree seats on the new

carriages, it being no longer required; and to increase the iron guard on the outer side in proportion with the box.

3. Stiff leather loops to be fastened on the inner side of the axletree-boxes, to assist the men in retaining their positions whilst passing over rough ground.

Advantages.

1. A simple way of carrying the detachment—No. 1 mounted, No. 9 with the wagon, and three men on the gun-limber as at present; the remaining four are carried in such a manner, that on the gun halting for the purpose of coming into action, these men on dismounting are in their proper places for working the gun.

2. An increased amount of ammunition can be carried, equivalent to the contents of two axletree-boxes per gun.

3. The lid of the axletree-box can be covered with thin iron plate, and should open to the rear; so that on its being raised, it would afford a certain amount of protection to the detachment numbers working in rear of the axletree.

97. "Occasional Papers of the R.A. Institution."

The publication of these papers commenced in June 1858, and was discontinued after about two years.

The greater part of them are contained in a volume which has hitherto been offered for sale at 10s.

Many of the articles in this volume are of permanent value in connection with the science of artillery, but there are others on various subjects of only transient interest, which may now be considered to have lost their value.

The original price, 10s., is consequently more than could now be expected for the volume, and the Committee, at a meeting held 4th April, 1872, having taken these circumstances into consideration, decided that the volume bound in half-calf should in future be sold at 5s.

Among the papers of permanent interest in the volume, may be mentioned one by Capt. A. Noble, late R.A., "On the Application of the Theory of Probabilities to Artillery Practice," which, it is believed, was the first successful attempt to utilise the mathematical theory of probability in the comparison of the accuracy of shooting of two or more guns.

98. "Rough Rules for Gunners."

Captain Strange's card containing "Rough Rules for Gunners" is now out of print, and is besides in some respects behind the times with regard to the information afforded.

Captain Strange has been informed, and requested to re-cast the card in such a manner as to accord with the latest regulations. Notice will be given when it is ready for re-issue.

99. List of Service Ordnance and Ammunition.

A revised copy of this table, in which the list of service fuzes recently issued to members has been embodied, and a table of energies and velocities at various ranges of the projectiles of all heavy armour-piercing guns added, is issued with the present number.

100. German 8½-in. Gun.

(Communicated by Lieut.-Colonel W. E. M. Reilly, C.B., R.A.)

Construction.—This gun of 8½-in. calibre is a breech-loader, having its breech closed by a wedge, in the centre of which is the vent, nearly in prolongation of the axis of the bore. It is of cast steel, and consists of an inner tube surrounded by nine cast steel hoops, shrunk on. The inner tube is the full length of the gun, 15 ft. 8½ ins., and may be considered of three thicknesses:—First, that about the loading-chamber and vent-piece, where there are no hoops. The next portion is cylindrical and rather thinner, and reaches to about half the length of the gun. This is belted by one layer of five hoops, the rear one of which is very narrow, the front ring being broad, and being also the trunnion ring. Round this layer, and over the powder-chamber, is a second layer of one broad hoop. The third portion of the tube, extending to the muzzle, is conical, and has three narrower hoops forming on the exterior surface steps adjoining the five hoops above-mentioned. At this junction is a ring, half in the tube and half in the hoops, which prevents the tube breaking away to the rear from the system of hoops.

Weight.—The weight of the gun is 9 tons, including vent-piece, which weighs 7½ cwt.

The axis of the trunnions passes through the axis of the bore.

There is no preponderance.

The rifling consists of thirty grooves, whose driving edges have a twist of 1 in 38 calibres, or 2° 38′ 42·6″.

Breech Ring.—At the end of the bore is a breech ring, which is set in an enlargement of the rear edge of the loading-chamber. This ring is hollowed out to the front, so that the action of the gas merely presses it tighter against the enlargement in which it is set.

Wedge.—The wedge is also of cast steel, is very slightly tapered, and enters its chamber from the left. In shape it is cylindro-prismatic, its front being a plane, its rear semicircular in section. Its motion is effected with great facility by means of a screw working in two collar blocks, one at either end of the wedge, which may be termed the carrying screw. This screw works against a half female screw in the top of the wedge-chamber. The screw is worked by a wrench. On the front of the wedge is a circular steel plate of slightly larger dimensions than the height of the wedge. This is hollowed out towards the front, and pierced through the centre for the vent; but as it is necessary to preserve contact between this plate and the breech ring, it can be advanced by placing a thin brass plate beneath it.

In order to press the face of the wedge firmly against the breech ring, there is in a slot in the rear part of the wedge a screw, on which works a collar having three teeth on one side of its exterior. When the wedge is home, by a half turn to the right, this screw carries the collar round with it, so that its teeth fall into corresponding slots in the side of the wedge-chamber. By continuing the operation of screwing, the screw works in the collar (which is now fixed), and thus forces the wedge further home, and at the same time its face against the breech ring. On the

end of the wedge a ring handle is provided, to be used in the event of the "carrying screw" getting out of order. A chain attached to the wedge, and also to the gun, regulates the distance to which the former can be withdrawn.

The wrench is 20 ins. long, and available both for the "carrying screw" and also for the "wedge screw." The wedge can be worked by one or two men, but in the event of this power being insufficient, a piece of cast-iron gas-piping is put on the wrench to increase the leverage.

Loading-Box.—The withdrawal of the wedge admits of the insertion of a "loading-box" through the end of the breech, the front end touching the breech ring, the rear end being rounded off. It is a tube of cast steel, and is kept in its proper position during loading by two latches, which turn on pivots in the breech and "catch" against two bearer pins. It is probable that a "shell" or half-cylinder will be introduced to supersede this "box," which will have the advantage of being lighter.

Vent-Bush.—The vent-bush passes through the wedge in prolongation of the axis of the bore, when the breech is closed, to avoid weakening the gun. It is of steel, having a copper ring in front of it; this ring can be renewed when worn out.

The bush is somewhat thicker in its front part than elsewhere, to secure its position; its rear end is closed by a piece of metal working in a concavity in the breech-piece, on a pivot. This has a slot cut in it to take the friction bar of the tube when placed in the vent.

Sights.—The gun is provided with two fore-sights and tangent scales, the latter graduated in degrees up to 15°.

Projectiles.—The projectiles provided for this gun are chilled and common shells, $2\frac{1}{2}$ calibres = 20 ins., the head being 1·3.

Chilled Shell.—1·3 of a calibre, the rounding of which is obtained by a circle whose radius equals twice the diameter of the shell without the lead coating. Its bursting charge is 2·42 lbs., and the length of the hollow is limited so as to leave the whole of the head solid. The base is closed as in the British service, with the exception that the plug is provided with a ring by which the shell is hooked to the tackle in raising it. For moving the shell a short rope is provided, having a hook at one end and an eye at the other. There is a loop in the rope which is passed over the point of the shell when the hook is attached to the base ring.

Common Shell.—The common shell has also a length of $2\frac{1}{2}$ calibres, of which one is that of the head. There are two extractor holes in the head, to enable it to be lifted by means of a clip.

The burster is 11 lbs.

For facility of fabrication, a hole is made in the base, which is filled up by a left-handed screw plug.

Cartridge.—The cartridge, $37\frac{1}{2}$ lbs., contains $23\frac{1}{2}$ layers of hexagonal prisms, 19 in each layer, or 447 prisms, and is 24·2 ins. in length. The material of the cartridge is silk. The 31-lb. cartridge has 368 prisms, and is 20 ins. in length.

The cartridges have, therefore, hexagonal form, with the edges rounded off.

Friction Tube.—The friction tube is of quill, at the open end of which is choked in a short piece of quill containing the detonating composition and a wooden plug, through which passes a brass friction, its outer end terminating in a ring, its inner end being turned back.

The Lanyard.—The lanyard has two branches, one end in a loop which is laid over the tangent scale; and thus during the service of the gun the lanyard is permanently attached. The other branch, which has the hook at its extremity, is provided with a loop which is hooked on to the bearer pin or hook, and thus provides a similar arrangement as in the British naval service.

Rapidity of Fire.—It is considered that this gun can be properly laid and fired at the rate of one round per minute.

Penetration.—No data are given as to range or elevation, and little as regards penetration, but it is calculated that the chilled shell will penetrate at 500 yds. a target having 8 ins. of iron, with teak backing of 10 ins. thickness, and double inner skins, each of $\frac{3}{4}$-in. iron.

Loading.—After loading, the loading-box must be withdrawn, to allow the wedge to be screwed home. The withdrawal of the wedge and clearing the vent are performed during the running up of the gun.

The Gun.

Breech or muzzle-loading	B.L.
Calibre ...ins.	8·44
Grooves, number	30
Pitch of rifling	2°38′42·6″, or 1 in 68 cals. for driving edge.
Length ... over all ...ins.	188·64
Length ... of bore ... „	162
Length ... of rifling ... „	126·38
Breech preponderance...lbs.	0
Weight of piece ...cwts.	180, 15·81lb. including vent-piece.
Material and method of construction	Cast steel.
System of breech-loading	Wedge.
Initial velocity with battering or highest charge...ft. per sec.	1284·56 for hardened shell.
Rapidity of fire	1 round per minute.

Ammunition.

Com. shell	diameter ...ins.	8·44 / 8·11
Com. shell	length ... „	20·59
Com. shell	weight, filled...lbs.	174·16
Com. shell	bursting charge „	11
Battering shell or shot	material	Chilled iron.
Battering shell or shot	diameter ...ins.	8·44 / 8·1
Battering shell or shot	length ...ins.	20·59
Battering shell or shot	weight, filled...lbs.	277·15
Battering shell or shot	bursting charge „	2·42
Battering or highest charge of powder	„	37·48
Service or ordinary, do.	„	30·86

101. Account of the Bursting of an 11-in. Cast Steel Krupp Gun, at Cronstadt, on Sept. 29, 1871. Extracted from the "Archiv für die Artillerie und Ingenieur Offiziere des deutschen Reichsheeres." Berlin, 1872.

(Communicated by Lieut. F. E. B. Loraine, R.H.A.)

An article which lately appeared in the Russian "Invalides," and was from thence transferred to the "Militair Wochenblatt," relative to the bursting of an 11-in. Krupp gun at Cronstadt, on October 11, 1871, is worthy of notice. As, however, the explanation of the mishap which is there attempted contains so much that is unintelligible, and, as far as it is intelligible, admits of serious question, we purpose, before placing it before our readers, to offer the following sketch of the attendant circumstances.

The front conical part of the gun burst as far as the front strengthening ring on the first occasion of being fired with a charge of 90 lbs. of prismatic powder and a double shell weighing 495 lbs., after two rounds had already been fired with 64 lbs. of prismatic powder. The cone broke into two parts, the line of breakage being nearly perpendicular to the axis of the piece; the rear and shorter part (about a third of the length of the cone) was itself separated into two smaller pieces by a longitudinal fracture. The front part was burst into four larger pieces. The broken surface of the body of the gun ran irregularly, partly under the ring, partly outside it, and the bursting took place (probably) when the base of the shell was from two to three feet from the muzzle of the gun. The gases which streamed out of the broken part of the gun to the rear knocked down part of the gun detachment, without, however, injuring anyone. Some of the fragments which flew to the rear conformed precisely to the direction imparted to the gun on recoil; others fell straight to the ground. Of those which flew to the front, two fragments ricochetted several times on the ground, and eventually settled in the sea, at a distance of about 33 yds. from the gun, conforming in their flight to the direction of the projectile. One of the latter fragments has already been recovered. A larger fragment, which was broken off close to the strengthening ring, still lies in the sea.

To judge from the appearance of the broken surface, the steel was faultless, so no blame can be attributable to it; and by means of several impressions of the lands and grooves taken at the place where, from the surface of the fracture, we may infer that the breakage began, the probable conclusion has been arrived at that the shell was jammed in the bore. Precisely the same arrangements were made for loading with the double shell as with shot of ordinary length, so that the powder chamber was shortened by about 2·3 in., and the pressure on the shell and the bore consequently increased. In addition to this, some of the other double shells which were experimented with displayed a very porous surface.

At the manufactory the following rounds were fired out of the gun—viz., one with 66, one with 77, and four with 88 lbs. of prismatic powder, and in each case a full sized projectile weighing 517 lbs.

We now proceed to quote the article extracted by the "Militair Wochenblatt," from the Russian "Invalides":—

"The chase or unstrengthened part of the gun burst on the first occasion that it was subjected to a charge of 100 lbs. (Russ.) of prismatic powder, and a projectile

weighing 550 lbs. (Russ.), a special committee having been appointed to superintend the experiment.

"The bursting was not caused by the jamming of the shot, as the lands and grooves were everywhere quite uninjured (?),* but in the opinion of the committee it was probably due to a flaw in the metal near the muzzle; and this opinion was founded on the general direction of the fracture, on the appearance of the metal at the fracture, and on the position of the fragments torn from the gun. The most characteristic circumstance was the tearing off of some of the fragments close to the muzzle, where on one of the surfaces of breakage a fibrous expansion of the metal was not observable, while it was to be found on all the others. Such a crack, however, entirely without indentations, notches, or crumbled bits, is peculiar to metal which has been burst at a spot where there had previously been a flaw (?).

"Experience teaches us that such flaws originate at the boring of guns out of cast (and not wrought) metal, on the surface of which hollow spots are discernible. Experience has equally taught us that such flaws are only to be found in the chase of a gun—never in the chamber. When the gun is bored out, most of these flaws disappear, but they are sometimes so fine that the eye cannot detect them, and when they remain on the surface of the bore they may cause the bursting of the gun. However, this but rarely happens, and the writer knows but of one case in which it has happened.

"At Slatrusk a star-shaped flaw was discovered in a 4-pr. steel gun, after it had been bored out. When the gun was further bored out the flaw disappeared, but a very careful examination revealed traces of it, as fine as hair, at the muzzle of the gun (were these traces offshoots from the star-shaped flaw?). This gun was then subjected to the most careful experiments, and at the 813th round the muzzle was torn off, and the fracture was found to be in the same direction as the above-mentioned flaw (?).

"This was analogous to the bursting of the 11-in. gun, with this difference—that in the one case the previously existing flaw was pointed out, in the other it was not. The largeness of the charge had nothing to do with the matter, but the sole origin of the mischief was a pre-existent flaw in the bore of the gun. Flaws are often to be found in cast-iron and bronze guns, without necessarily causing them to burst. They can never be quite avoided. The expansion of the powder gas at the muzzle of an 11-in. gun is as nothing against the resisting power of steel tubes of such a calibre. It is therefore highly probable that the bursting of the gun in question was caused by a flaw near the muzzle."

However we may be disposed to examine the explanation here attempted, we must necessarily come to the conclusion that it cannot hold water for one moment, since no one could *really point out* in the fragments that were picked up the flaw near the muzzle ascribed to the gun. The proof of such a flaw should be demanded, because every crack produced by the force of powder, or in any violent way whatever, shows a crystalline or fibrous structure of the metal, which is not the case with cracks, whether in the shape of holes or fissures, which are produced during the founding of the metal, and the difference between the two is such that it can be plainly recognised even by the eye of the uninitiated. But, as regards the circumstance from which it has been inferred that one may assume the existence of a fault in the metal arising during manufacture from the fact that one crack displayed no

* The notes of interrogation are in every case those of the writer in the "Archiv."

fibrous structure while the others did, it is well known that this fibrous structure tends to disappear, and to give place to a clean, smooth, crystalline surface, in proportion to the suddenness with which the bursting of the metal takes place. Now, the beginning of every bursting of a gun naturally lasts a shorter time than the end of it, and so different structures will continually be recognised in cracks which have not been quite simultaneously produced, provided the excellence and homogeneity of the metal of the gun leave nothing to be desired.

Whether the cause which made the 11-in. Krupp gun burst at the muzzle will receive a completely satisfactory clearing up may be left undecided. Meanwhile we may rest satisfied that the present is an exceptional case, and to anticipate all exceptional cases we may characterise as an impossibility. In any case it would be easy at once to make the muzzle ends of rifled guns stronger than is customary, or even to strengthen them not immaterially by the addition of a reinforce ring and ojee; but even this arrangement would not obviate the possibility* of a gun thus strengthened occasionally splitting at the muzzle.

And here let us call to our recollection the Lancaster guns which were brought into use in the Crimean war, and subsequently abolished. These guns had smooth elliptical bores, with an increasing twist. Their elongated projectiles were made to fit the bore, in which they received the same rotatory motion round their longer axes as the projectiles of rifled guns. As the Lancaster guns were muzzle-loaders, and had therefore windage, a jamming of the projectile occasionally took place, the result of which was either the breaking up of the same, or the splitting of the chase of the gun. The construction of these guns was therefore a failure.

If any dirt, or indeed any foreign matter, be collected in the chase of our present rifled guns, the projectile will not take time, on the discharge of the gun, to force it out, but will force its own way over it. Then if the lead coating cannot find sufficient room, the natural result is either the splitting of the steel tube or the smashing of the projectile.

At experiments which were made with smooth-bore muskets more than thirty years ago, merely for the purpose of clearing up this matter, barrels which had previously been stopped with sand or dirt were almost invariably split at the muzzle by the round lead bullets which were fired out of them.

Again, with reference to the position of the fragments of the 11-in. gun, we may remark that when on the bursting of a gun parts of the same fly in a forward direction, such can only have been effected by means of the shot impelled by the explosive force of the charge. Also, the mere falling of some of the fragments in a downward direction, and the fact that some of those fragments were not also hurled sideways by the force of the powder, may, if not with certainty, at least with great probability, lead to the final conclusion that the chase of the gun was certainly not burst, but simply split by a jamming of the projectile in the bore, although this might also have been accompanied by a sideward motion of the fragments.

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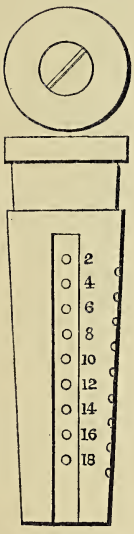
* The German word is "Unmöglichkeit," which must either be a printer's error, or a result of the very obscure, involved style which characterises the writer in the "Archiv."

102. Description of a Dummy Time Fuze.

(Communicated by Captain H. D. Evans, R.A.)



Service fuzes being too expensive to use at drill, and it being, however, essential to bore, fix, and uncap a fuze for every round, the following description of dummy fuze is suggested, having been used with great advantage by the writer:—

1. The fuze to be made of beech wood, and similar in shape to the service fuze, but a little longer and larger in diameter, in order that when fixed it should only go a short way into the shell. It could then be easily withdrawn from the shell, and if necessary the boring also could be examined by the instructor before it was handed to the No. 3.

2. The centre to be hollowed out from the bottom to within an inch of the top, and to be filled with sand or sawdust; the bottom to be covered over with paper only, so that the filling may be renewed; and on the top of fuze the false head of a screw should be cut.

3. A groove ·5 in. wide to be cut round the neck of fuze, and filled up with black Berlin wool, to represent the quick-match of the service fuze; the top edge of groove to be ·25 in. from the top of the fuze.

4. ·25 in. from the lower edge of the quickmatch-groove must be cut grooves ·25 in. wide for the holes. They must reach down to the bottom of fuze, and be just deep enough to prevent the paper over them being torn when the fuze is fixed in the shell. In these grooves the holes must be bored; the top one of the even numbers ·25 in. from top of grooves, and the remainder ·25 in. apart. The holes must be made fully the size of the bit of service borer, so that when the latter is used at drill, the wood between the holes may not be damaged, and might be filled with putty, so as to offer some resistance to it.

5. The figures on the dummy fuze must be sunk a little, or perhaps only stamped deeper than on the service fuze, otherwise after a few days' drill they would be obliterated. The figures must naturally be opposite to the holes.

6. Over the holes a strip of black, red, or grey paper, with the dots at proper intervals corresponding to the holes, should be pasted.

7. Slips of paper 3 ins. long and ·25 in. wide, with dots ·25 in. apart (the top dot of even numbers ·25 in. from end of strip, and the top dot of odd numbers ·375 in.) should be provided, so that a fresh strip of paper can be pasted over the holes at the end of each day's drill.

8. The exact method of uncapping cannot be shown; for if the whole of the black wool (quickmatch) were exposed, it could only be done once at each day's drill. The following plan might, however, be adopted:—Six vertical strips of black or red paper (5 secs. or 9 secs. fuze) about half an inch wide and a trifle more than an inch in length, with a piece of white tape under each strip, might be pasted over the black wool. By this means the process of uncapping might be done at any rate six times for each fuze, and these strips replaced for the next drill.

103. The following table gives the calculated remaining velocity and energy, at various distances, of Palliser projectiles fired with battering charges of P. powder, from the 12-in. rifled M.L. gun of 35 tons.

Projectile, 700 lbs. weight; 11·92 ins. diameter; charge, 110 lbs.

Range.	*v*.	Total energy.	Energy per inch of shot's circumference.	Range.	*v*.	Total energy.	Energy per inch of shot's circumference.
yds.	ft.	ft. tons.	ft. tons.	yds.	ft.	ft. tons.	ft. tons.
0	1300	8205	219	2200	1094	5810	155
200	1277	7915	211	2400	1080	5660	151
400	1256	7655	204	2600	1068	5535	147
600	1236	7415	198	2800	1056	5415	144
800	1216	7175	192	3000	1044	5295	141
1000	1196	6945	186	3200	1032	5175	138
1200	1177	6725	180	3400	1022	5070	135
1400	1159	6520	174	3600	1012	4970	133
1600	1141	6320	169	3800	1002	4875	130
1800	1125	6140	164	4000	994	4795	128
2000	1109	5970	159				

W. H. N.

104. The following abstract shows the pressures observed from time to time during practice at Shoeburyness with the 12-in. rifled M.L. gun of 25 tons, Expl. No. 372.

Date of experiment.	Nature and weight of projectiles.	Charge and approximate muzzle velocity.	No. of round.	Pressure by crusher gauge in tons per square inch at	
				A Axis, or end of bore.	B 12 ins. from end of bore.
22. 9. 71.	Com. shell, 495 lbs.	85 lbs. P. 1350 ft.	1	17·4	16·1
"	"	"	2	17·8	17·7
"	"	"	3	16·6	15·8
"	"	"	4	16·7	16·3
"	"	"	5	16·8	14·7
"	"	"	6	19·8	17·2
9. 4. 72.	Shrap. shell, 533·5 lbs.	55 lbs. P. 1100 ft.	1	12·8	11·7
"	"	"	2	13·5	13·6
"	"	"	3	12·2	11·7
"	"	"	4	11·6	11·9
20. 9. 72.	Case shot, 246 lbs.	85 lbs. P.	1	14·5	14·0
"	"	"	2	15·1	15·2
"	"	"	3	15·2	15·2

W. H. N.

105. Continuation of the Plan for carrying the Detachments with Field Artillery. (*Vide* "Short Notes," p. 157).

(Communicated by Major S. Penny, R.A.)

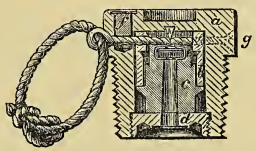
In consequence of having learnt that the present weight behind the team cannot be exceeded, I propose as follows :—

1. That the amount of ammunition equivalent to the contents of two axletree boxes be taken away from the gun-limber. This will reduce the weight on the shaft horse.

2. If the axletree boxes are not increased in size, as proposed, then to increase the lids only, both in front and rear, to allow of two men being carried on each axletree box.

106. Royal Laboratory Screw Percussion Fuze, G.S. (General Service).

(Communicated by Captain J. Sladen, R.A.)



a. Body.	*e*. Cap.
b. Guard.	*f*. Lead plug.
c. Pellet.	*g*. Safety pin.
d. Bottom.	*h*. Needle.

This fuze will act equally well from B.L. or M.L. rifled guns. Its use will probably be extended to the 40, 64-pr., and 7-in. B.L. guns, and up to 80-pr. M.L.R.

It is used with common, segment, or shrapnel shells, and will act either on graze or impact. It is tapped with a screw thread to fit the G.S. gauge of fuze hole.

Its construction is given in the engraving, and also the names of the several parts of the fuze.

The body, guard, and bottom plug are made of gun-metal, the pellet of lead and tin, the cap of copper, and the safety pin of twisted brass wire.

The head of the body is pierced to receive the safety pin; the lead plug serves to close the hole left when the safety pin is withdrawn. The safety pin is prevented from dropping out by twisting the ends of its wire outwards, as shown in the engraving. The hole at this end of the pin is covered by a strip of metal, soldered on. A loop of cord is attached to the safety pin, in order that it may be withdrawn easily. A needle point is fixed in the centre of the head, above the cap in the pellet.

The guard is a gun-metal collar, having two holes through which the safety pin passes, so as to keep it in position.

The pellet has a cap fixed in its head containing a large charge of cap composition (fulminate of mercury, sulphide of antimony, and chlorate of potash), protected by a very thin piece of sheet brass. On the exterior of the pellet are two projecting feathers, on which the guard is supported when the safety pin is withdrawn.

The bottom plug screws into the body, and has a central hole, closed by a thin brass disc.

The fuze is screwed into the shell by the G.S. key, which fits into the slot in the head. The safety pin is withdrawn just before the shell is placed in the bore of a B.L. gun, and in the case of a M.L. gun when the shell is placed in the bore.

Action.—On the shock of discharge the guard sets back, shearing off the two feathers, and fastens on to the pellet, the metal of the latter expanding into the undercut recess shewn in the guard. The lead plug prevents the flash of the discharge from entering the fuze through the safety pin hole. On graze or on impact—as the case may be—the pellet and collar fly forward, the cap is exploded by striking against the needle point, and the flash from cap blows out the disc closing the bottom plug, and explodes the shell.

107. Fuze, Time, Wood, R.M.L. Ordnance.

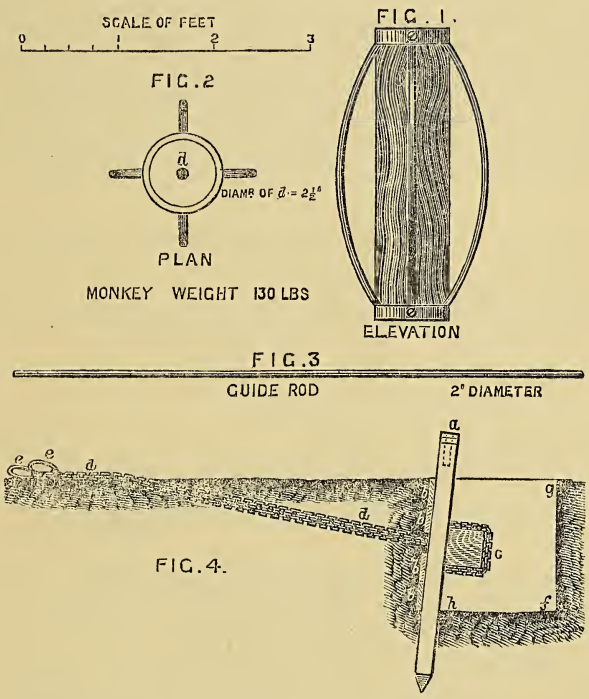
(Communicated by Captain J. Sladen, R.A.)

Mark III. will be sealed for future manufacture, differing from II. in the head projecting farther from the shell, in having a larger groove containing more priming, and in having a copper band. The paper lining will be reduced in thickness, and the powder channels will be so placed as to be midway between the composition channel and exterior, and reduced 1 in. in length.

This pattern is found more certain of ignition than Mark II., and is also less liable to cause prematures with heavy charges, owing to the powder channels being well protected.

108. Description of the Swiss Pile-driving Machine.

(Communicated by Major Downes, R.A.)



The "monkey" (Figs. 1 and 2) should be at least 12 ins. in diameter, and about 3 or 4 ft. in length. The handles are made of rope or iron rods, the monkey of wood. Four men can work it easily.

A hole (*d*) of $2\frac{1}{2}$ ins. diameter is bored down the centre of the monkey and burnt smooth.

Each picket to be driven requires to have a hole bored in the centre of the head to a depth of 9 ins. and of $2\frac{1}{8}$ ins. diameter. Into this a guiding rod of 2-in. iron 6 ft. long is temporarily placed, and the monkey is worked up and down upon it.

The pickets should have an iron band round the head, to prevent them from splitting.

This appears to be the simplest description of machine for driving the pickets which it is necessary to use when making holdfasts for sheers with which to lift guns of 12 tons and upwards.

The holdfast is thus constructed, agreeably to Minute $\frac{\text{Gen. No. } 5}{5288}$:—

A hole (*b*, *h*, *f*, *g*) 15 ft. × 4 ft. × 4 ft. is dug, and four planks (*b*, *b*, *b*, *b*) placed on edge against the side nearest the points from which the strain is to come.

Four pickets, 8 ft. × 6 ins. diameter (one shown at "*a*"), are driven behind the planks at intervals 3 ft. 6 ins. apart, to a depth of 3 ft. below the bottom of the trench.

One-third of the trench is now filled in, and a beam about 15 ft. × 12 ins. × 12 ins. (*c*)—an old gun will answer—is placed horizontally against the four pickets.

The centre of a chain, 1 in. or more in diameter, is fastened round the centre of the beam, and the two ends are brought between the second and third planks, through a narrow trench cut at right angles to the original one, to the surface; the trenches are then filled in, and the strain taken in the two ends of the chain.

Spars for sheers to lift 25-ton guns should be 45 ft. in length and 20 ins. diameter in centre.

For 12-ton guns, with spars of 45 ft., 17 ins. at the centre; with spars of 40 ft., 16 ins.

109. New Wrought-iron Field Artillery Carriages.

(Communicated by Captain W. Kemmis, R.A.)

A short description of the following field artillery carriages may not prove uninteresting, as they are likely to supersede the present service patterns, in future manufacture, viz.:—

Nature.	Weight empty.	Tonnage.
	cwt. qr. lb.	tons.
9-pr. M.L.R. gun-carriage	10 2 17	4·079
" limber	10 3 16	
" wagon	14 0 1	4·493
" limber	10 3 16	
16-pr. M.L.R. gun-carriage	12 1 24	4·079
" limber	11 0 22	
" wagon	14 1 13	4·493
" limber	11 0 22	

9-pr. M.L.R. Gun-Carriage.

The main points of difference between this and the present service carriage, are as follows:—

The substitution of a wrought-iron for a wooden axletree-bed; the construction of the brackets, in which the plate is placed on the inner instead of the outer side of the bracket frame; and the form and manner of the connection of the trail plate.

The axletree bed, as just stated, is formed wholly of wrought-iron, and has the axletree riveted into it; both together constituting, as it were, a beam of box girder section. The axletree forms the bottom of the box; a piece of angle-iron, riveted along each side of the body of the axletree, the sides; while the top is formed by a broad plate riveted upon the upper sides of the angle-iron pieces. This construction gives great increase of strength; for though the wood bed furnished a convenient means of attachment between the axletree and body of the carriage, it did not support the axletree in an efficient manner.

The brackets are housed over and riveted through their frames to the axletree-bed; they are also secured to it by the front transom, which is riveted to them and to the bed; and, further, by a small bracket stay between each bracket and the back of the bed.

Placing the plate upon the inner instead of the outer side of the bracket frame gives greater strength to the bracket, by bringing the plate more under the trunnions, or, as it may shortly be expressed, "nearer its work." This mode of construction has also the advantage of being the more convenient for manufacture.

The transoms are of plate-iron; the front transom has a frame of angle-iron riveted to it in front, and a piece of angle-iron along each side in rear; and the second transom has a piece of angle-iron riveted along each side, both front and rear.

The trail-piece is formed, not as in the present service carriage, to lap over and under the point of the trail, but to lie partially between the bracket sides. This form gives a stronger neck to the trail eye, and is much easier of manufacture than the old pattern. A bearing plate is bolted beneath the point of the trail.

The top plate of the axletree-bed forms a suitable support for the axletree-boxes, which are attached to it by nib irons on the inner and screws on the outer side.

The wheels of the carriage are the same as those of the present service carriage—viz., Madras pattern, of the 2nd class, 5 ft. high, and with a tire $2\frac{1}{2}$ ins. wide.

The elevating screw box is secured in its sockets on the brackets by cap squares, which makes it more convenient for removal, when required.

The other fittings and articles belonging to the carriage are similar to those of the present service carriage.

9-*pr. M.L.R. Limber.*

This limber differs from the service limber in having a wrought-iron instead of a wooden axletree-bed, and no block between the latter and the limber-hook.

The axletree-bed is formed in a similar manner to that of the gun-carriage, but being of necessity deeper than the latter, its sides are constructed of plate-iron, a piece of angle-iron being riveted along each for the top plate to rest upon and be secured to.

The futchells, of tee-iron, are let into the bed beneath the top plate, and are riveted to its angle-iron. The centre futchell is bent and its end riveted to the back plate of the bed, while the outer futchells project to the rear for the support of the top plate under the limber boxes; the latter plate is also strengthened by a stay near each end.

The limber-hook is forged with three long arms by which it is riveted to, and at the same time held at a sufficient distance from, the rear of the bed; the rivets holding the upper arms have collars upon them.

The platform and footboards are both 10 ins. wide, and beneath the front of the latter a slat is secured across the futchells, to prevent a horse getting his leg between the splinter bar and the board.

The splinter bar is of plate-iron, trough-shaped, as in the service limber.

The wheels, fittings, and articles belonging to the limber are also the same as in the latter.

9-pr. M.L.R. Ammunition Wagon.

This wagon differs very considerably in its construction from the present service pattern. Its axletree-bed is of wrought-iron, built up in the same manner as that of the gun-carriage—namely, by angle-iron riveted along each side of the body of the axletree, and a plate over the angle-iron pieces.

The perch is formed of two brackets, in a somewhat similar manner to the trail of the gun-carriage, connected by a nose-piece with eye for attachment to the limber, and by three collar bolts. The nose-piece is formed in the same manner as the trail-piece of the gun-carriage. The brackets are of channel iron, the trough or channel in each being turned outwards, and in rear of the axletree-bed the lower part sloped off. This form of perch gives greater strength against any twisting strain.

The perch lies across the top plate of the bed, each bracket of the former being connected to the latter by a piece of angle-iron rivcted to both, and also by rivets through the lower flange of the channel-iron.

The sides of the wagon are of angle-iron, fish-bellied; they rest upon the axletree-bed, and are connected to it by means of angle-iron. To the outside of each side, and to the bed, is also riveted a stay of angle-iron, which forms, as it were, the continuation of the top plate of the bed.

A platform plate is rivcted across the perch and sides beneath the front and rear platform boards.

The wheels and the boards are the same as in the service pattern wagon.

The block for the axletree arm to carry the spare wheel is formed by riveting a plate to the inside of each bracket, and projecting upwards from it. The plates are connected by two collar bolts, and have the arm, which is of wrought-iron, solid, riveted between their upper extremities. Upon the perch, extending under the footboard, the usual wooden stay is riveted.

The other fittings and articles belonging to the wagon are the same as in the present service pattern.

16-pr. M.L.R. Gun-Carriage, &c.

The 16-pr. gun-carriage is similar to that of the 9-pr., but has heavy instead of light field wheels—*i.e.*, with a tire 3 ins. wide instead of 2½ ins., and is fitted with a trail box.

The limber and ammunition wagon are identical with those of the 9-pr., except in having heavy wheels, and in the internal fittings of the boxes.

ERRATUM.

Page 168, sec. 107, heading, *for* "Fuze, Time, Wood, R.M.L. Ordnance," *read* "Fuzes, Time, Wood, Boxer, M.L., 20 secs. and 5 secs., Mark III."

110. Note on the new Method of Controlling the Recoil of Heavy Guns at Proof, by Major E. Maitland, R.A.

Up to the present time, heavy guns have been carried down by rail from the Gun Factories on trucks to the butt, and have then been mounted for proof by means of a crane (constructed to lift 30 tons), on a strong iron carriage, fitted with expanding sides, to take guns of weights varying from 12 to 38 tons.

It is now proposed to extend the rails opposite the firing bays, so that a heavy gun may be fired from a specially constructed travelling truck; thus dispensing with the expanding carriage and crane altogether. The axis of the gun on the truck will be parallel to the rails, and the truck and gun will recoil along the line. There are three adjacent bays formed to receive the proof projectiles of heavy guns. In order to utilize them all, it is only necessary to curve the line of rail sufficiently to permit lines drawn from the bays to form tangents to the curve; the distance of the firing points from the butt being enough to render the angle of incidence unimportant.

By carrying back the rail in a curve of contrary flexure, a second series of firing points is obtained, at an increased distance from the bays. The railway is then carried back in a straight line, so that from the most distant firing point the recoil may be direct. On account of the nature of the ground, it is found expedient to bring the gun to a standstill within a distance of 120 ft. from the rearmost firing position. Assuming the weight of the heaviest gun likely to be used at 80 tons, and the weight of the truck at 5 tons, we have $W = 85$. Supposing this gun to throw a shot of 1600 lbs., with a muzzle velocity of 1400 ft., we have

$$\text{initial velocity of recoil} = V = \frac{vw}{W} = 11{\cdot}76 \text{ f.s.}$$

Hence the work contained in the gun and truck at starting will be

$$\frac{WV^2}{2g} = 182{\cdot}6 \text{ foot tons.}$$

Allowing a margin for exceptional cases, we will put this energy at 250 foot tons.

The work done in stopping the recoil is given by the formula

$$W(\sin\alpha + \mu\cos\alpha)\,S,$$

which may be put

$$W(y + \mu x);$$

μ being the co-efficient of friction, which, with strong rough rails and truck wheels, will not be less than $\frac{15}{2240}$, or ·0067. Hence

$$\frac{WV^2}{2g} = W(y + \mu x).$$

and this will give the height of the slope (or y) at any given distance x, whether the railway be horizontal, or carried up an inclined plane, or so constructed that the incline be an upward curve.

In the present case, since $x = 120$ ft.,

$$y = \frac{250}{85} - {\cdot}0067 \times 120 = 2{\cdot}14 \text{ ft.};$$

$$\therefore \tan\alpha = \frac{2{\cdot}14}{120}, \text{ and } \alpha = 1^\circ\ 1'{\cdot}5.$$

Suppose, now, that it were necessary to bring the gun up at 15 ft., we should have

$$y = \frac{250}{85} - \cdot 0067 \times 15 = 2 \cdot 84;$$

and α would be 10° 43′.

In this case it would probably be found expedient to construct the railway so that it should curve upwards, and the semicubical parabola would be found to be a highly suitable curve for the purpose. Its equation is

$$y^2 = a^2 x^3;$$

$$\therefore\ a^2 = \frac{y^2}{x^3} = \cdot 00239,$$

$$\frac{dy}{dx} = \frac{3a \times \frac{1}{2}}{2} = \tan \theta.$$

Hence the angle of ascent would increase from 0 to 15° 31′.

Returning to our heaviest gun, and assuming that, contrary to expectation, the recoil has carried it to the summit of the slope, we have next to calculate, on its running down again, what velocity it will acquire by the time it reaches the bottom. It is evident that gravity will bring it down, and friction will retard it. Hence we have

$$\text{acceleration} = g\ (\sin \alpha - \mu \cos \alpha) = v \frac{dv}{ds}.$$

Integrating,

$$S = \frac{v^2}{2g\ (\sin \alpha - \mu \cos \alpha)} + C.$$

$$\text{When } S = o \quad v = o, \quad \therefore\ C = o;$$

$$\therefore\ v = \sqrt{2gs\ (\sin \alpha - \mu \cos \alpha)};$$

and putting $S = 120$ (strictly 120 sec 1° 1′·5), $v = 9 \cdot 26$ at the bottom of the slope.

The gun will then travel over about 100 ft. on the level, and will then rise up another inclined plane made to consume the remaining energy; after which, it will run down again, and come to rest not far from its first position when fired.

In the foregoing calculation the resistance of the air is neglected, being small and on the right side.

111. New Iron Siege Carriages. By Captain W. Kemmis, R.A.

The following iron carriages are proposed for the siege train, and of them the first named has recently been approved, namely:—

Nature.	Weight, empty.		
	cwt.	qrs.	lbs.
40-pr. M.L.R. of 34 cwt., gun-carriage	24	2	0
64-pr. M.L.R. of 64 cwt. (II. & III.), gun-carriage	30	2	0
8-in. M.L.R. of 46 cwt., howitzer-carriage	40	1	14
Siege limber	11	0	14

40-*pr. M.L.R. Gun-Carriage.*

This carriage is constructed in the same manner as the 9-pr. M.L.R. carriage Mark II. (described in a previous "Short Note;") that is to say, the brackets have the plate—which is lightened out—on the inner side of the angle-iron frame, the axletree-bed is of wrought-iron, and the trail-piece fits between the points of the brackets instead of lapping over them.

The transoms—of which there are two—are each formed of plate, riveted to a three-sided frame of angle-iron. They are riveted to the brackets, the connection of the second transom to the latter being strengthened by small bracket stays, while the front transom is riveted to the bed. A bracket stay is also riveted to the front, and another to the rear, of the axletree-bed, and to each bracket, in order to unite the bed more firmly to the brackets.

The wheels are the Madras pattern, 1st class, 5 ft. high, shod with ring tires 6 ins. wide; the flanges of the nave do not project beyond the pipe-box; their track is 5 ft. 2 ins.

The trunnion-holes—as in the wooden siege gun-carriages—are "firing" and "travelling," the height from the ground to their axis being 4 ft. 5 ins.

The gun is elevated or depressed by means of an elevating arc attached to it, which passes between a pinion and a friction wheel upon the inside of the right bracket. The pinion is turned as required by means of a worm-wheel and worm-shaft with hand-wheel.

The carriage is fitted with two trail handles, an iron box for a spanner, and rests in which to carry the elevating arc when the gun is in the travelling trunnion-holes. The fittings for the drag-shoe and chain are upon the left of the carriage.

64-*pr. M.L.R. Gun-Carriage.*

This carriage is similar to that for the 40-pr., and has the same height of axis of the trunnion-holes.

8-*in. M.L.R. Howitzer-Carriage.*

The carriage proposed for the 8-in. howitzer differs from the two preceding in having brackets of double-plate construction with wrought-iron frames, and in the axletree and its bed, which is formed merely by a piece of angle-iron riveted along each side of the axletree, passing through instead of lying beneath the brackets, while a bottom plate is added, extending from the rear transom to the breast of the brackets. This construction is rendered necessary, as it is intended that the howitzer should be fired from the carriage with the wheels off as well as on.

The lower parts of the brackets are extended to the front, to prevent the carriage tipping when the howitzer is fired, the wheels not being on; and the bottom plate is rounded in rear, to prevent it injuring the ground platform.

The rear transom has angle-iron riveted across the top in rear, which is also riveted to the brackets, and both transoms are secured by double angle-iron.

The elevating gear is similar to that for the 40-pr. and 64-pr.; but, while attached to the right side, it is worked at the left.

Siege Limber.

The siege limber is constructed in the same manner as the field limber Mark II. (described in a previous "Short Note.") In addition to being riveted into the bed, the axletree is further secured by a clip near each shoulder.

The wheels are the heavy field wheels, Madras pattern (*i.e.*, the same as for 16-pr. M.L.R. limber).

The splinter-bar is fitted for four-horse draught, in the same manner as the wooden siege limber.

112. Formulæ for Computing the Number of Barrels piled in Magazines, by Captain S. E. Pemberton, R.A.

Case 1.—Pyramid pile.

$$S = 1 + 2 + 3 \ldots\ldots + n;$$

where S = number of barrels,

n = number in bottom row.

$$\therefore\ S = \frac{n\,(n+1)}{2}. \quad \ldots\ldots(1)$$

In an incomplete pyramid pile,

$$S = \frac{n\,(n+1)}{2} - \frac{(m-1)\,m}{2} = \frac{n^2 - m^2 + n + m}{2}$$

$$= \frac{(n+m)\,(n-m+1)}{2}; \quad \ldots\ldots(2)$$

where m = number in top row.

Case 2.—Where *one* end of the pile rests against an upright, and *the top row does not touch* the upright.

$$S = n^2 - m^2;$$

where n = number in bottom row, and m number in top row.

Suppose the pile continued till $m = 1$. Then,

$$S = 2\,(1 + 2 + 3 \ldots\ldots + n) - n - 1$$

$$= n\,(n+1) - (n+1) = (n+1)\,(n-1) = n^2 - 1; \quad \ldots\ldots(3)$$

and in an incomplete pile,

$$S = (n^2 - 1) - (m^2 - 1) = n^2 - m^2. \quad \ldots\ldots(4)$$

Case 3.—If the top row touch the upright.

$$S = n^2 - m^2 + m. \quad \ldots\ldots(5)$$

Case 4.—Where the barrels are piled *between two uprights* so that if bottom row $= n$, second $= n - 1$, third $= n$, and so on.

If top row $= n - 1$—*i.e.*, if top row do not touch the uprights,

$$S = mn - \frac{m}{2} = \frac{m}{2}\,(2n - 1); \quad \ldots\ldots(6)$$

where m = *number of courses.*

When top row $= n$—*i.e.*, when top row touches uprights,

$$S = mn - \tfrac{1}{2}\,(m-1) = \frac{m\,(2n-1)+1}{2}. \quad \ldots\ldots(7)$$

These results, being only calculated for piles of one barrel in depth, must of course be multiplied by the number of barrels in the *depth* of the piles.

113. 10-in. M.L.R. Carriage and Platform, Casemate, Mark II. By Captain W. Kemmis, R.A.

The carriage and platform lately approved (L. of C. § 2513) for the 10-in. M.L.R. gun of 18 tons, when mounted in a casemate, may be described as follows:—

Carriage.

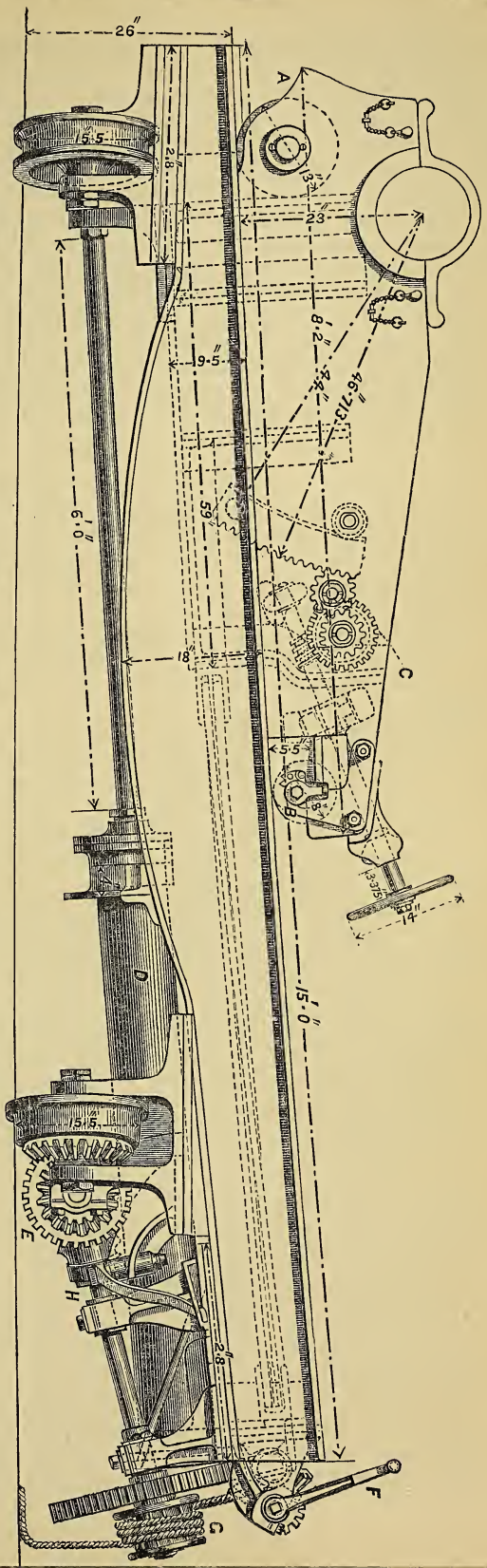
(Weight 67 cwt., tonnage 4·776 tons).

The carriage is of "double-plate" construction, built upon Captain Scott's plan, already much adopted in the navy; that is to say, the brackets are very low, and in order to admit of sufficiently high elevation being given to the gun (10°), which the adoption of low brackets would otherwise prevent, the bottom of the carriage is in the form of a well, into which the breech of the gun can sink as the muzzle is elevated.

The advantage of having the brackets of a carriage low may be said to be threefold—viz., it decreases the twisting strain on discharge upon the carriage, by giving the force in action but a small moment about the extreme rear bearings of the carriage; it permits of the platform upon which the carriage rests being high; and it increases the stability of the carriage.

The frame of each bracket—*i.e.*, the part which lies between the plates, and through which the rivets holding the latter pass—is of cast-iron, great strength not being required in it; in fact, the frame in this and all other double-plate garrison carriages really only serves as a packing-piece, to give the plates rigidity and to furnish sufficient thickness for bearings in the bracket side.

Two transoms connect the brackets. They are "box-shaped"—that is, with back, front, and ends of plate-iron united along the edges by angle-iron. To the ends of these



boxes the brackets are riveted—the former projecting 8½ ins. below the latter—and beneath them the bottom plate, completing the well of the carriage.

The rear rollers of the carriage are quite hidden in their recesses in the brackets. They run, in the usual manner, upon an "eccentric shaft," secured in the brackets by "drop-plates" and thrown into action by iron-pointed levers applied in movable sockets with pawls. The front rollers are sufficiently uncovered to admit of their being "scotched," if necessary, in running the carriage up.

The elevating arrangement is the "self-clamping" worm-wheel gear, fitted on the inside of each bracket but worked on one side only at a time, the worm-shaft of the side not in use being retained out of gear by means of a clutch.

A bracket for the attachment of the piston-rod of the hydraulic buffer is bolted beneath the front of the bottom plate and holding-down clips to the front transom.

In the rear of the rear transom there is a hole to receive the T (shank) of the block (double) of the running-back tackle, in which it is secured by giving it a quarter turn.

The carriage is fitted with capsquares, and has upon the front transom a buffer-block. When the gun is run-up, the axis of the trunnions is 4 ft. 2½ ins. from the ground.

Platform.

(Weight 106 cwt., tonnage 6·037 tons).

The striking difference between this platform and that hitherto used for the 10-in. gun, when mounted in a casemate, is its greater height, which has the advantage of admitting of the use of large trucks whereby the movement of the platform on the racers is facilitated, and also of giving space beneath for the gear by which the motion is imparted.

The sides of the platform are constructed in the same manner as all platforms for very heavy guns—namely, "fish-bellied" in form, built up of plate and T iron, the latter forming the under and upper surfaces and united by the plates which are riveted to them.

The sides stand 4 ft. 1½ ins. apart, connected by four transoms bolted to them, two in front and two in rear, also by a top plate in front and a bottom plate in rear. The transoms are each formed of plate, riveted to an angle-iron frame.

Beneath the sides, with packing-pieces between, at the proper distance apart, the truck plates are bolted, to which in the usual manner the flanges for the trucks are attached. The front truck plate is slotted to give access to the nuts and keys between the two front transoms.

The trucks are of wrought-iron and run upon steel axles; they are 18 ins. in diameter, hollow soled (the rear trucks having but one flange) and coned to suit the "A" pivot—that is, 6 ins. to the front of the muzzle of the gun when the latter is run-up.

For traversing, toothed gear is applied, as in all platforms for the "A" pivot, to the rear trucks. It is worked by a winch-handle *F* at each side, the same handles serving to work the running-back tackle by the provision of a clutch *H* to disconnect that portion of the gear which acts immediately upon the trucks, and by the addition of a bollard *G* for the running end of the fall. The rear block of the tackle is, for use, attached to the rear transom of the platform in the same manner as the front block is to the carriage, while a leading block on the platform guides the fall to the bollard.

The hydraulic buffer *D*, for checking the recoil, lies very low in the platform, on account of the well of the carriage. It is supported in rear by a bearing formed of plate and angle-iron bolted to the rear bottom plate and strengthened by stays, and in front upon one of angle-iron, to which latter it is secured by a holding-down band. The cap of the buffer abuts against the plate of the rear bearing, and is secured from moving forward by two small pieces of angle-iron. The bolts retaining these pieces pass through the bearing-plate, and must be taken out before the buffer can be removed. To admit of filling the buffer, a hole is made in the bottom plate of the platform over the filling hole. The latter is closed by a special plug sufficiently long to project through the bottom plate.

The platform is fitted with india-rubber stops, on the top plate for the carriage when run up, and in the third transom for it on recoil, with eye-bolts, side-arm brackets, sponge tank, pointer, snatch-blocks for loading tackle, movable stage for No. 1, and with a cover over the exposed parts of the traversing gear.

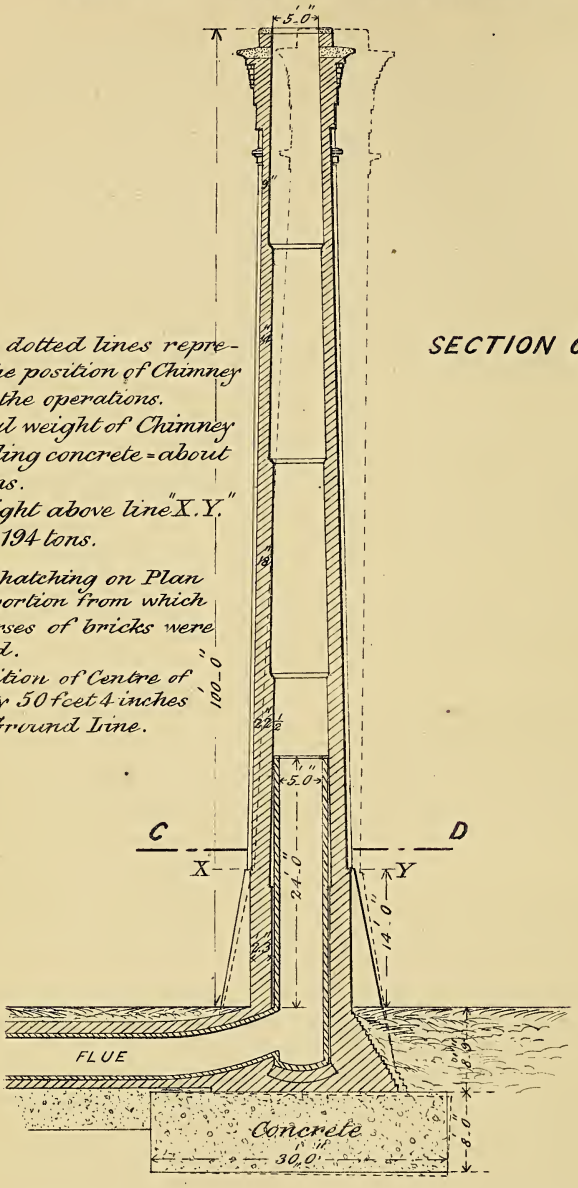
STRAIGHTENING OF CHIMNEY

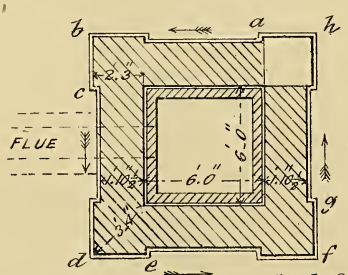
AT THE GAS WORKS

ROYAL ARSENAL WOOLWICH.

NOTES. (1.) The dotted lines represent the position of Chimney before the operations.
(2.) Total weight of Chimney including concrete = about 720 tons.
(3.) Weight above line "X.Y." = about 194 tons.
(4.) The hatching on Plan shews portion from which two courses of bricks were removed.
(5.) Position of Centre of Gravity 50 feet 4 inches from Ground line.

SECTION OF CHIMNEY





SECTIONAL PLAN AT LEVEL C.D.

Scale for Section.
feet 10 5 0 10 20 30 40 50 ft.

Scale for Plan.
feet 10 5 0 10 20 ft.

114. Description of the operation of Straightening the Brick Chimney-shaft of the Gas Works at the Royal Arsenal, Woolwich, in March, 1874, under the superintendence of Bt.-Lieut.-Colonel Scratchley, R.E., Inspector of Works, Manufacturing Departments, and Lieut. Watson, R.E.

The following description of this interesting operation may prove of service; and as it can without doubt be applied to chimney-shafts of any height, it will, in most cases, be worth a trial before adopting the expensive course of rebuilding shafts which have become inclined.

The operation at the Arsenal was carried out by Mr. Ralph Hall, of 126, North Frederick Street, Glasgow—a well-known "Steeple Jack" who has had great experience in all matters relating to defective chimney-shafts, the repair and refixing of their caps, and lightning conductors.

The price paid for the work was £50—a very moderate sum, when it is considered that the cost of rebuilding the chimney, with a good pile foundation, and removing the old shaft, was estimated at £650.

It will be seen that the operation is very simple and apparently unattended with any risk, but the operator must possess great coolness and experience.

The Arsenal shaft which is 100 ft. high, was erected in 1860.

From borings taken prior to its erection, it was found that the subsoil consisted of clay resting on an inclined bed of peat, situated at a considerable depth below the surface of the ground.

With this bed of clay it was considered at the time unnecessary to have a pile foundation, and a mass of blue Lias lime concrete, 30 ft. square and 8 ft. thick, was provided.

Soon after the chimney was completed, it was observed to be inclining from the perpendicular, and in December, 1861, it was leaning over 19 ins. to the south, and 24½ ins. to the west.

Observations were taken with a theodolite, and continued at intervals up to the middle of 1873, when it was found that the inclination of the chimney had increased to 33½ ins. to the south, and 42½ ins. to the west.

The increase in the inclination was not uniform, but became more rapid between the years 1871 and 1873; consequently—although the limit of safety (72 ins. of inclination) had not been reached—it was decided to attempt to straighten the chimney rather than to rebuild it.

It is difficult without a careful examination of the foundations, which would be a costly matter, to assign an exact cause for their failure; but it is quite possible that the inclined bed of peat, being of an unequal thickness, may have become compressed by the weight of the chimney—estimated at about 20 tons.

After consultation with Mr. Hall, it was determined to cut out the brick-work at top of the chimney base, where its thickness is 2 ft. 3 ins. at the angles and 1 ft. ins. at the sides, exclusive of the fire-brick lining to the flue, which as it was g out had to be removed.

An old steam boiler tube was erected to serve the purpose of a temporary chimney, and a scaffold consisting of one plank supported by poles, having been constructed round the shaft at a convenient height, Mr. Hall—assisted only by one labourer—commenced to take out two complete courses of brick throughout the entire thickness of, and round, the chimney, excepting the S.W. angle, which when the chimney was straightened would be found to be at about the proper level. As the bricks were taken out—two courses at a time and two bricks wide throughout—they were replaced by two other courses of bricks of varying thicknesses set in sand mixed with just sufficient lime to make it bind and keep it from falling out when the sawing, hereafter described, commenced.

This part of the operation occupied Mr. Hall and his assistant about eight working days, after which the straightening of the chimney was commenced by the very gradual removal of the layers of sand and courses of bricks previously put in, an iron cross-cut saw, $\frac{1}{16}$ of an inch thick and provided with very coarse teeth, being used for the former—Mr. Hall working on the outside, and his assistant on the inside, of the chimney.

As the sand on top of the upper course of bricks was removed by the saw, the shaft gradually settled down, turning on the S.W. angle as a fulcrum. The upper course of bricks was then taken out and replaced by thinner bricks or tiles set in sand and lime as before.

The sawing being resumed, the sand was worked out, the tiles were again removed and replaced only by sand, and so on.

As the process was continued the shaft came over imperceptibly until it reached a perpendicular position, when it was found that the N.E. angle had fallen $5\frac{1}{2}$ ins., the N.W. and S.E. angles 3 ins., while the S.W. angle had risen one quarter of an inch.

Observations taken with the theodolite shewed that the shaft was perpendicular on the south side, but 4 ins. inclined on the west side; as it was impossible to make it absolutely upright, in consequence of the chimney having originally inclined in a diagonal direction.

The last part of the operation was to replace the remaining bricks and tiles by bricks set in cement, and cut to suit the wedge-shaped opening left in the brickwork. The work was completed in three weeks.

It is essential to ensure success that the following points be attended to:—

1. The sand and bricks must be very carefully packed, so as to leave as little as possible of the shaft unsupported.

2. This packing of sand and bricks must be removed very gradually to prevent the shaft from returning to a perpendicular position too rapidly.

115. The new Weapon for the Austrian Field Artillery. (Communicated by Lt.-Col. W. H. Goodenough, R.A.)

The bore of this gun is 6·6 ft. long; it has 24 grooves, of a depth ·04 in.; and weighs, with round wedge breech-piece, 9 cwt. 66 lbs. The projectile consists of a long, so called, double-ringed shell, $2\frac{1}{2}$ calibres in length, with four copper rings on

the exterior. The inner surface forms the *kernel* of the shot, the hollow of which contains the charge, ·42 lb. weight. This *kernel* looks like a crystallised body which consists of a number of small pyramids, whose sides are ·39 in. long and whose bases are united by thin cross-pieces and ribs. These pyramids fit into corresponding recesses on the inner sides of the outer casing. In consequence, the projectile, on explosion, breaks up into 50 or 60 pieces of ·5 oz. to 2·5 oz. weight, besides 20 smaller pieces. The shell loaded weighs 13·98 lbs. The cartridge contains 3·3 lbs.; when for vertical (high-angle) fire ·88 lbs. The sides of the iron carriage are made of steel plates. The axletree-boxes have seats for the gunners. The limber (which is also of iron) and the carriage have both the same sized wheels, 51 ins. high—"Thonet wheels, with iron naves"—which renders the exchange of a damaged spoke in the field possible without the necessity of each time taking the wheel to pieces.

The gun and carriage together weigh 13 cwt. 28 lbs.; the gun complete, together with limber and 34 rounds of ammunition packed therein, weighs 35 cwt. (about 1 cwt. more than the Austrian 8-pr. bronze gun). The draught it entails on each horse (six in a team) is 787 lbs. when five men are sitting on the axletree and limber-boxes.

The initial velocity was 1548 ft., as against 1122 ft. with 8-pr. The space covered by the shot when fired against an object 5 ft. 10 ins. high was twice as great, and the range attained with similar angles of elevation nearly $\frac{1}{3}$ greater than with the 8-pr.

Comparison.—50 per cent. of the shot, at ranges of from 1000 to 3000 paces, fell within a space of 12 to 21 paces long, ·3 to 2·1 metres wide, and ·7 ft. to 6 ft. in height.

Against 40 to 57 paces, 1·5 to 5·8 metres, and 1·33 to 9·6 metres with the 8-pr.

With a 5 ft. 10 in. object at 1000 paces from the gun, 100 per cent. hits, 89 per cent. at 2000, and 50 at 3000, as against 66, 27, 10 with 8-pr.

Krupp has given a half-battery which will soon be fitted out (Wednesday, the 26th August, 1874). A comparative trial of the two guns was made, when Krupp's was much the best. This half-battery will take part in the field manœuvres.

116. Table showing the Weights of the Carriages of Field Batteries in Marching Order with the Detachments Mounted. By Capt. S. C. Kyle, R.A.

The weights behind the teams of the R.M.L. 9-pr. and 16-pr. guns are calculated with 5 men on the gun-carriage; as it is customary at field days with other troops, when moving from one position to another, to carry 3 men on the gun limber and 2 men on the axletree seats.

With 5 men on the carriage it will be seen that the teams of the R.M.L. 9-pr. and 16-pr. guns have a greater weight to draw than the teams of the smooth-bore 9-pr. and 12-pr. bronze guns had respectively.

The weight of the wagons is calculated with 6 men mounted; as they would carry this number on the line of march or at regimental drills.

Weights of former and present Equipment of Field Batteries in "Marching Order," with the gunners mounted.

Weights of former equipment taken from "Handbook for Field Service," 1867; weights of present equipment from "Handbooks" for 9-pr. and 16-pr. R.M.L. guns.

Weight of a gunner, 12 stone ..... = 1 2 0 Weight of a gunner's kit and great coat, 28 lbs. = 0 1 0	9-pr. bronze.			9-pr. R.M.L.			12-pr. bronze.			16-pr. R.M.L.			Weight per horse.	
Gun.	cwt.	qrs.	lbs.	cwt.	qrs.	lbs.	cwt.	qrs.	lbs.	cwt.	qrs.	lbs.		cwt.
Gun, carriage, stores, &c.	40	0	12	35	1	18	45	1	2	42	0	24	9-pr. bronze gun with 6 horses ...	7·32
Drag-shoe and chain, not included in "Handbook for R.M.L. 9-pr."	0	0	0	0	1	22	0	0	0	0	0	0		
2 carbines and 2 sword-bayonets	0	0	20	0	0	20	0	0	20	0	0	20	9-pr. R.M.L. " " 6 " ...	7·37
2 gunners' kits and great coats	0	2	0	0	2	0	0	2	0	0	2	0		
Short traces and spare hames	0	0	16	0	0	16	0	0	16	0	0	16	12-pr. bronze " " 8 " ...	6·12
2 pairs traces for breast harness	0	0	0	0	0	10	0	0	0	0	0	10		
2 limber gunners	3	0	0	3	0	0	3	0	0	3	0	0	16-pr. R.M.L. " " 8 " ...	6·32
	43	3	20	39	3	2	49	0	10	46	0	14	16-pr. R.M.L. " " 6 " ...	8·43
2 gunners on axletree seats, and 3rd gunner on limber	0	0	0	4	2	0	0	0	0	4	2	0		
Total weight	43	3	20	44	1	2	49	0	10	50	2	14		
Wagon.														
Wagon, stores, &c.	38	0	2	40	1	0	40	0	8	42	0	13	9-pr. bronze wagon with 4 horses	12·19
6 kits and great coats	1	2	0	1	2	0	1	2	0	1	2	0		
6 sword bayonets	0	0	15	0	0	15	0	0	15	0	0	15	9-pr. R.M.L., " "	12·72
2 carbines	0	0	16	0	0	0	0	0	16	0	0	0	12-pr. bronze, " "	12·72
6 gunners	9	0	0	9	0	0	9	0	0	9	0	0	16-pr. R.M.L., " "	13·18
	48	3	4	50	3	15	50	3	11	52	3	0		

117.—Mounting two 11-in. Muzzle-loading Rifled Guns on Westmorland Fort, Spike Island. By Lt.-Col. W. Denis-de-Vitre, R.A.

Cork Harbour,
1st April, 1875.

(1) The two 11-in. guns for No. IV. Bastion, Fort Westmorland, Spike Island, were slung between two Admiralty barges at Haulbowline, and dropped on the beach at Spike Island. They were parbuckled up to high-water mark, and then transported on a 25-ton drug up the glacis on oak skidding (steepest gradient 1 in 10), into and along the bottom of the ditch to the foot of No. IV. Bastion; it having been determined to hoist these guns from the bottom of the ditch, by means of 66-ft. spars, on to the sill of the embrasure (height of the escarp, including skidding, 26½ ft.)

(2) The Royal Engineers performed the following services:—The upper surface of the ditch was removed, and a bed of Portland cement concrete was laid to receive the shoes for the feet of the sheers to rest in, at 7 ft. from the plinth of the escarp wall. The concrete was carefully laid, and the shoes bedded in it at right angles to the line of its face. As pickets could not be driven into the ground, two 1½-in. wrought-iron eye-bolts were let into the foot of the wall, for securing the feet of the sheers, and two rough timber decks were constructed for the winches.

(3) The "List of Stores for Rigging and Erecting Sheers for Embarking, Disembarking, Mounting, and Dismounting Guns of 25-tons" was adhered to, with the following extra stores and precautions, rendered necessary by the adoption of 66-ft. spars (diameter in middle, 2 ft. 1 in.) instead of 45-ft. spars.

Extra Stores.—40 fathoms 4-in. white rope, for lashing head of sheers, 2 pieces of 4-in. rope of 12 fathoms each, for lashing straps for fore and back guys to spars; the 15-ft. straps being 2 ft. short to take a turn round these spars, one piece of 6-in. white rope, 12 fathoms, to lengthen the 19-ft. sling for the main tackle fall. (This sling was lengthened about 7 ft., to allow of its receiving the main tackle blocks.) Two double 18-in. blocks were used for the front guy, which afterwards became the back guy; the sheers were raised by one single and one double blocks. The gun was slung with a 1½-in. holdfast 10 fathom chain, there being no slings, and two 18-in. single blocks were used at the feet of the sheers instead of snatch-blocks.

(4) The winches to work the falls were bolted down to the timber decks, which were sunk about a foot and weighted with the wrought-iron platforms belonging to the guns. The feet of the sheers were in the ditch, whilst the head rested on the counterscarp and was lashed in a half raised position. The sheers were raised without a derrick, and when up stood nearly parallel to the face of the escarp (angle about 5°), and the guns barely touched the face of the wall as they gradually rose. The time in hoisting the last gun, from taking the weight to lowering on to the skidding, was 1½ hours.

The 66-ft. sheers are capable of lifting guns in this way 28 ft.

To obviate the occurrence of a blank page in binding these "Short Notes," the preceding page will be reprinted in a future issue.

W. G. BRANCKER,

Major R.A.,

Actg. Secretary R.A.I.

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